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Railway Renaissance

For over twelve years the industries of this country have pursued a policy of expansion. The need to re-equip after the war, the people's desire to raise their standard of living, and the Government's insistent call to export, have all combined to produce better results in each succeeding year. But there has been one extraordinary exception—the railways.

Though the volume of the country's goods and services has been increasing, and though most of the nationalised industries have participated in this increase, the railways have reacted to their financial difficulties by a cheese-paring policy. Uneconomic branch lines and stations have been closed and every effort made to retain only the more profitable parts of their business even though, as railways, they hold a monopoly. The modernisation programme seemed to herald a new outlook, but the demands of the unions were too pressing and impatient. The Government and the Transport Commission face the old dilemma. The background is a fall in freight traffic in the ten years since nationalisation of 3 per cent, though passenger traffic has gone up 10 per cent.

Part of the trouble has been the low salaries and wages paid to railwaymen. Indeed it has been a tenet of many politicians and union officials that the overall prosperity of British industry could be attributed in no small measure to cheap internal transport—transport made cheap by low wages. On the other hand, it is also certain that neither freight charges nor fares can go up without seriously endangering the efforts of industry to keep a footing in traditional markets, far less gain new ones. This is the predicament that, not for the first time since nationalisation, the Government, the Commission and the railway unions are now facing. To their credit they all seem to recognise that there are the two sides to the problem. The unions know the dangers of increased costs, though that they will accept the consequence seems no more hopeful to-day than on the previous occasions when railway wage disputes have come to a head.

There also appears to be a very genuine desire on the part of the Government to see wages and salaries brought into line with those in other industries. The meeting between the Premier, Sir Brian Robertson, chairman of the Commission, and the leaders of the unions, inaugurated a new approach in railway negotiations. If the Commission can make some economies, then the Government will allow the savings to be passed on in terms of wage increases. No doubt the Government hope that if the railwaymen come to believe that they are getting a square deal, there would be more hope of effecting the improvements expected from the modernisation programme. The Government have promised to speed up the programme by restoring the cuts made last October if the Commission and the unions—without reference to industry or the travelling public—can agree on some economy measures. Just how much money is involved in the Government's offer is set down in a Weekly Survey note in the following pages. Taken all round, however, the emphasis is on economy, cuts and contraction. Such a policy has a disheartening effect on the staff and it is not the way to make the most profitable use of the railways' capital equipment. In a compact, industrial island the consequent high traffic density is the railway operators' opportunity.

Sir Brian is reported to have drawn up a list of economies and presented it to the Minister of Transport. If he wished to offer a pay increase of 3 per cent all round, he would have to find cuts worth £10 million annually. What chance has he of being original? The unions are not likely to stand for any of their members being declared redundant and they are too well entrenched behind the principle of one man, one job, so that a high proportion of the labour force is not gainfully occupied throughout each shift. If only the unions would take a more enlightened view of this issue some economy might be effected which is not just one more cut in the services. But the railway unions represent one of the largest labour forces in British industry; there are therefore limits to the restraint that the union leaders might exercise. They cannot take the risk of getting out of touch with the union members and their aspirations.

There is certainly room for effecting economies by a critical revision of organisation and methods—as indeed there is in most industrial companies. Some little-publicised progress has already been made in this direction; as there is a shortage of professional engineers on the railways, the regions have used the services of consultants (both managerial and engineering) to good effect. The infusion of new blood and new ideas will pay dividends. There is no reason why the railways should not move with the times and have the same virile policy as the rest of the country. They should resist any attempt to hold them back. If they do not —if they acquiesce to a policy of play-safe—they must not be surprised if Brigadier Lloyd and his rail-into-road league catch up on them.

Cover Picture. *Spherical-roller bearings of the kind illustrated are widely used in heavy-duty applications, since they are self-aligning and have high carrying capacity. The larger bearing has an outside diameter of 720 mm (28¼ in) and the smaller 240 mm (9½ in). They do not of course represent the limits of the range.*

* * *

Plain Words

It is only three weeks since I said I admired a man who is not given to pulling strings but who gets on by his own initiative and hard work. Imagine my surprise, then, on reading this advertisement in a personal column a few days ago: "Will successful business lady or lady of social standing help hard working, ambitious, Professional Engineer with extensive and expanding business covering the British Isles. It is not always 'what you know' but 'who you know'."

Take a lady into partnership! The spark of radicalism in me (perhaps I should say the embers) shone forth when I read that. Here, in semi-socialist England, is a man who believes that the social values and atmosphere of Victorian and Edwardian days still persist in the 1950's, in spite of the bloodless revolution which we have gone through. I had come to think that only the Liberal Party was hanging on to those quaint ideas.

I didn't know whether to envy or pity the engineer in his self-appointed task of interviewing all the successful business ladies and ladies of social standing who would reply to his advertisement. A successful business lady might be rather frightening. By definition she is obviously capable of running men's lives for them; a firm hand would have to be used in managing her, and that would take up much of one's time and energy. But I rather like the idea of a lady of social standing, provided she has a sense of humour and could carry the whole thing off as a huge joke. If, into the bargain, she were an amateur television star, she might even do some quiet advertising to the millions for his extensive and expanding business. A lady of that quality could certainly help in many ways, but popular publicity and acclaim is a very slippery slope and they would have to watch that neither of them went too far down it.

Considering the difficulties which face the anonymous engineer, he deserves all the success he achieves. Indeed, the advertisement itself, in spite of its nature, shows that he is an independent character, not afraid to strike out directly for what he wants even if the method has to be unconventional. His business is clearly doing well, and he intends it to do better. It's a pity there are not a few more like him. Unless we want to be tramps and hermits, we ought to be thankful for all the hard working, ambitious professional engineers the country can muster. And for the good ladies who help—bless them.

CAPRICORN

Weekly Survey

Lord Heyworth on Advertising

The whole of the speech of Lord Heyworth, chairman of Unilever, at the company annual general meeting last week, was on the subject of advertising. "It is a matter of public interest," he said, "and as such open to comments." The Unilever group spent £83 million in 1957 on advertising their products in over a hundred countries. He told the group's shareholders that last year Unilever were compelled to increase their advertising expenses, "with a consequent reduction in net profits despite a greater turnover." Nearly half the total expenditure was in North America, where more is spent as a proportion of the value of sales than anywhere else in the world.

Lord Heyworth argued strongly that the advertising of products was essential to a free economy. There existed no other economic means of communicating with customers and potential customers—in Unilever's case, with 1,800 million people. "Freedom of choice for someone who is not made aware of the alternatives from which choice can be made is an illusion," he said, and this includes "freedom to try to persuade others to your way of thinking." There is also the contribution sales promotion makes to economic stability. When demand flags, advertising tends to be increased—as in Unilever's own case in 1957—"to re-animate economic activity." Properly handled advertising establishes a more predictable demand for products and "thus mitigates violent fluctuations."

Lord Heyworth's remarks are of considerable interest to manufacturers of capital as well as consumer goods, because the former tend to neglect communications with customers. Only few engineering companies—and in general the most successful ones—have invested in advertising on a considerable scale. The problem of establishing a regular contact with the users of a machine is of course less than in Unilever's case, since there are few machine makers whose potential customers are numbered in six figures. Nonetheless, our competitors in the United States, Germany and elsewhere tend to rely on advertising and other means of promoting sales more than we do. The management of small as well as large firms in the engineering industry will find much in Lord Heyworth's speech which is pertinent to their own problems.

Oil Throws a Shadow

When there is discussion of the possible effect on this country's exports of a recession in the price of world commodities, specific cases quoted tend to be such traditionally vulnerable commodities as rubber, cocoa, wool and wheat. Oil has enjoyed such bounding prosperity for so long that it is rarely placed with the other commodities in discussions of this kind. Yet the recent decline in oil prices and the slackening in the rate of world expansion in the industry is beginning to cast a shadow.

Prices have in fact been dropping for diesel oil since early 1957 and for petrol since the early autumn. Fuel oil prices have eased since the turn of the year. Expansion of capacity throughout the world has gone ahead but at a more cautious pace of late.

The slightly more cautious note in the industry is beginning to have an effect on the equipment and fabricating industries which supply it. It has already been announced that United Kingdom orders for petroleum equipment at £134 million last year were £20 million lower than in 1956, although higher than in 1955. Too much should not be read into year-to-year fluctuations in orders, but this drop in the figures put out by the Council of British Manufacturers of Petroleum Equipment is the first fall since 1953. The drop has been particularly noticeable in tubulars, pipe fittings and valves. Stewarts and Lloyds have announced cuts in output at Corby and there is also short-time being worked at the company's plants in Scotland which are particularly dependent on the oil industry, though the position at Corby has been eased by a useful order for steel tubes from the Chinese Government. It has also to be remembered that oil is a significant example of a world industry which has changed its view from expansion to caution under the impact of the American recession and United Kingdom exporters are feeling the pinch.

Electricity Headaches

The heavy electrical industry in this country must be prepared to face a change in pattern which will be widespread in its effects. The change is being brought about by the increase in size of generating units and the corresponding decrease in their number.

The steady rise in prices since the war has forced the Electricity Authority to place efficiency as number one priority. In general it is true to say that the larger electric plant is the more efficient one, and in particular the higher the temperatures used the higher the efficiency of conversion from fuel to power. As a result, the sets now on order for the CEGB are mostly in the 200 MW class with a top size of 550 MW, the last being of the cross-compound form to come within the limits of road transport. From this it follows naturally that the number of sets needed will be greatly reduced as compared to those that have been installed since the war. In fact, whereas in recent years ten sets have been put into commission yearly, future programmes will only be calling for two conventional sets and two nuclear sets per annum. The orders placed therefore will be large in value but small in number and must inevitably impose their pattern on the industry as a whole.

The other problem that faces the CEGB is the low average load factor that exists to-day and the very slow rate at which it is being improved. The figure last quoted was 46 per cent suggesting that more than half the plant installed throughout the country is only required to handle daily peak loads All the estimated costs for electricity generated by nuclear plant have assumed that it will be operating at full load; only under these conditions will the cost approach that of steam generation. However, at the present rate of increase of load factor and with the present plant commissioning programme, nuclear stations will be working on peak loads by 1972. In other words they will be operating far below their economic level, with a consequent increase in unit costs.

This situation can only be met effectively by an all-out effort to improve the load factor. One way is to encourage the use of off-peak heating equipment such as storage heaters and floor-warming systems, both of which could go quite a long way to easing the problem. Another possibility is the construction of pumped-storage schemes. The possibilities of the cross-Channel cable link for spreading the load are as yet rather unknown, but the last forecast suggested that some easing might be expected from it.

Diesel Difficulties

Two main reasons have been given for the decision to cease production of diesel engines at the Leeds works of J. and H. McLaren Limited: local reorganisation within the Brush Group

to which McLaren's belong and excess capacity for diesel-engine production due to increased German competition in export markets generally and particularly in the Near and Far East. It is expected that between 500 and 600 of the total of 786 employees at the Leeds works will become redundant.

The fact that McLaren's are experiencing difficulties in export markets probably implies similar difficulties for other British manufacturers in this field—one in which the British industry has previously held a strong position. Total British exports of compression-ignition engines (other than for marine propulsion, motor vehicles, tractors and aircraft) fell from 1,046,000 h.p., valued at £14·2 million in 1956, to 993,468 h.p., valued at £13·9 million, in 1957. But while exports of engines of 300 b.h.p. and over increased, those of smaller engines fell from 798,846 h.p. to 695,697 h.p. The McLaren range extends from about 30 h.p. to 200 h.p. and it is within this range that the main fall in exports has occurred. At the lower end of the range there has been growing competition from commercial vehicle manufacturers. Moreover the Brush Group as a whole have been exporting an exceptionably high proportion of their total output and it was stated in November last year that McLaren had exported 70 per cent of their output to date.

Railway Moneys

The only long-term solution of the railway wages problem lies in the hope that the completion of the modernisation programme will result in sufficient increase in traffic to permit the payment of higher wages, probably to a substantially reduced number of employees. Yet this is not to say that the cuts in the modernisation programme last autumn were a major factor in producing the present wage deadlock nor that the restoration of these cuts could make an important contribution to the solution of the problem in the immediate future.

The exact effect of the cuts has never been specifically stated. The reduced level of expenditure by the Transport Commission was expected to be about £170 million in each of the years 1958 and 1959 of which about £135 million in the former year and £140 million in the latter would be spent on rail transport. These figures are not out of line with expenditure in 1957 nor with the overall estimate of £1,200 million to be spent over 15 years. Owing to inflation, however, the original programme is expected to cost about £1,500 million in all and holding the annual expenditure steady is therefore likely to result in a cut of about 20 per cent in real terms. However, a reduction of expenditure in real terms in 1958 and 1959 would not be likely to affect materially delivery of equipment this year or even in 1959.

Quite apart from the wage situation there is a strong case for completing the programme as early as possible. If the railways continue to lose traffic for too long they may find it difficult to regain even when modernisation is complete—the last railway strike showed that once plans are made for alternative transport it is a long time before the traffic returns to the railways.

Steel Looks Ahead

Commenting on the future outlook for steel in the 1957 annual report of the British Iron and Steel Federation, the Federation anticipates that steel output will be below capacity this year. It is hoped that total demand will be somewhat similar to the 1957 level. The trend of demand for steel overseas is uncertain, competition is expected to become keener and there is a hint that the industry may have to accept further cuts in export prices. Looking further ahead, the industry is now studying the question of raising its capacity above 30 million tons during the 1960's, a growth which the Federation hope will be stimulated by the establishment of the Free Trade Area. The development programme up to 1962 allows for an ingot steel capacity of 29 million tons by that date and a pig iron output of about 20 million tons. This last figure, if achieved, will make imports of pig iron and scrap marginal. Completing this development programme will involve a big expansion in both home and imported ore supplies, involving between 22 and 24 million tons of imported ore by 1962. A major expansion is also envisaged in home ore supplies amounting to about 30 per cent. In addition, Stewarts and Lloyds and the United Steel Companies are undertaking new exploration north of the River Welland which they will take further if the survey shows satisfactory results.

The Price of Delay

British Overseas Airways Corporation has estimated provisionally that its deficit for the financial year 1957 to 1958 will be about £2¾ million. This compares with a net profit of £303,000 last year, both figures being struck after a substantial charge for interest on capital. The Corporation is looking forward to improved results in the current financial year and forward bookings are at present encouraging.

While most of the net loss is accounted for in interest charges, there was a small operating loss of about £750,000 on the year. There have been two main causes of this. The first of these was the delay in the delivery of new aircraft, notably the Bristol Britannia. The second of these was the fall in receipts on particular routes such as the North Atlantic run.

These figures show that this country can import overseas recessions through the takings on its international transport routes more quickly than from its other export earnings, since air travel in particular is marginal for those who do not have to travel on business. The figures also show the vulnerability of airlines to delay in bringing into effect technical changes. The delays in the delivery of Britannias, like the trouble with other planes in previous years, has had a quick and serious impact on BOAC's income. This year certain advantages may be working in the Corporation's favour. It has made good progress in replacing obsolescent machines and the American recession may slightly slow down the rate of replacement by American airlines.

Letters to the Editor

TRAINING OF ENGINEERS

SIR, I was heartened to read your leading article "A.M.I.Mech.E." concerning the training of engineers (18 April, p. 481). It is most encouraging to find a leading engineering journal stating its views unequivocally on this subject.

British engineering is, I believe, suffering from the delayed effects of what one might call "analyticism" in the training of engineers. The worst direct cause of this has been the extremely limited relationship which has existed in the past between the universities and industry, and the consequent aloof attitude of academic staff towards industrial problems. Bernard Shaw's remark that "those who can, do; those who can't, teach," is, in general, true in engineering, even if one dissociates oneself from the sneer behind it. The result has been that engineering, which is at root a creative activity, has been taught primarily as an analytical process. This is not to imply that there has been a subversive process at work, but rather that we have acquired this peculiar structure for certain well defined social and historical reasons.

Furthermore, since some engineers have until recently considered themselves the inferiors of the scientists, they have been too ready to acquire the social gloss of the scientist by accepting, in some measure, his standards, and even his expressions.

Now I do not wish these comments to be interpreted as a resentment of scientists or the scientific method; quite the contrary. The criticism is rather of those in engineering who were ashamed to find that all aspects of their profession could not be easily pigeon-holed and catalogued. What should have given them pride has caused them pain.

The enormous problems of choice of alternatives in the day-to-day work of creative engineering and designing are the very basis of his work, and his training must in some way enable him to compound a multitude of minor decisions into a single major decision. A number of major decisions together may then combine to produce a piece of creative design in which the result is not necessarily the apparent sum of the parts. In engineering design it is a commonplace that two and two do not necessarily make four.

It seems to me that there has been an almost complete absence of any attempt by the universities to tackle this problem, even in an empirical way. Perhaps it is difficult to teach creatively, although I do not accept that it is impossible. It is surely possible, however, to encourage creativity. In any case, difficulties should not be made the excuse for failing to tackle this major problem.

Perhaps more than any other country we enjoy a particularly rich heritage of creative engineering, and this heritage we are in danger of despising. If we continue to do so we deserve the end which we shall surely get, which will be the reduction of the engineer to an insipid and poor imitation of a scientist.

To prevent any possible misinterpretation, I would add that I am an advocate of the scientific method, wherever and whenever it can be applied in engineering, and I consider that analysis is a vital component of engineering training. However, creation must come first, for without it there would be nothing to analyse. The educational problem is not one of absolutes or dogmas, but of emphasis, and I hope that your journal will continue its work of restoring the engineer's view that the solution of a design problem or the creation of a machine or mechanism, however simple, is no less honourable an activity than that of the man who, by its analysis, earns himself a Ph.D.

Yours faithfully,
H. MASHEDER.

James Gordon and Company, Limited.
Stanmore, Middlesex.
22 April, 1958.

ANODE AND POSITIVE

SIR, The letters from Mr. G. H. C. Nicholls (4 April, p. 419) and Mr. J. F. Perrin (18 April, p. 484) have driven me, too, into inspecting some dozen text-books, mainly written for students of physics. Of these, the large majority agree in restricting the use of the terms "anode" and "cathode" to the sections dealing with electrolysis proceeding under the influence of an external source of e.m.f., while the terms "positive" and "negative electrode" are used when referring to the plates of primary or secondary cells. Thus, the confusion is tacitly avoided.

In contrast to these, the *Admiralty Handbook of Wireless Telegraphy* (1938) defines and uses anode and cathode as synonymous with positive and negative electrodes. R. W. Pohl's *Physical Principles of Electricity and Magnetism* (1933) goes so far as to state "The positive electrode is often called the anode, the negative one the cathode. These terms have been adopted for conduction phenomena of all kinds." This might suggest that continental practice may differ from that adopted here, but Grimsehl in his *Textbook of Physics*, vol. III (1933), like most of the other sources consulted, defines the anode as "the plate connected to the positive pole of the source of electricity, i.e., the plate

Continuing Letters to the Editor

at which the positive current enters the liquid," and Carey Foster and Porter, founded on Joubert, also use standard practice.

But surely, Faraday, as the originator of the terms, must be allowed the last word. I happen to have inherited a copy of his *Experimental Researches in Electricity*, printed in 1849, and I hope that you may be able to find space to print the relevant paragraph, from Series VII, dated January 1834, which gives his full explanation of the terms, and which I have never seen reproduced elsewhere.

He states: " 663. The surfaces at which, according to common phraseology, the electric current enters and leaves a decomposing body, are most important places of action, and require to be distinguished apart from the poles, with which they are mostly, and the electrodes, with which they are always, in contact. Wishing for a natural standard of electric direction to which I might refer these, expressive of their difference and at the same time free from all theory, I have thought it might be found in the earth. If the magnetism of the earth be due to electric currents passing round it, the latter must be in a constant direction, which, according to present usage of speech, would be from east to west, or, which will strengthen this help to the memory, that in which the sun appears to move.

" If in any case of electro-decomposition we consider the decomposing body as placed so that the current passing through it shall be in the same direction, and parallel to that supposed to exist in the earth, then the surfaces at which the electricity is passing into and out of the substance would have an invariable reference, and exhibit constantly the same relations of powers. Upon this notion we purpose calling that towards the east the *anode**, and that towards the west the *cathode*; and whatever changes may take place in our views of the nature of electricity and electrical action, as they must affect the *natural standard* referred to, in the same direction, and to an equal amount with any decomposing substances to which these terms may at any time be applied, there seems no reason to expect that they will lead to confusion, or tend in any way to support false views.

" The *anode* is therefore that surface at which the electric current, according to our present expression, enters: it is the *negative* extremity of the decomposing body; is where oxygen, chlorine, acids, &c., are evolved; and is against or opposite the positive electrode. The *cathode* is that surface at which the current leaves the decomposing body, and is its *positive* extremity; the combustible bodies, metals, alkalies, and bases, are evolved there, and it is in contact with the negative electrode.

* *ἄνω upwards* and *ὁδὸς a way*; the way which the sun rises: *κατὰ downwards*, and *ὁδὸς a way*; the way which the sun sets."

Yours faithfully,
MICHAEL MILFORD.

11, The Cross, Derby.
26 April, 1958.

CORIOLIS ACCELERATION

SIR, Your correspondents, J. Pidduck (4 April, p. 420) and E. H. Bateman (18 April, p. 483), have shown methods of deriving the magnitude and direction of the Coriolis acceleration component. There is still a need to help students to visualise how this acceleration actually takes place. The following approach, while by no means rigorous, may be of assistance:

Use (r, θ) co-ordinates and consider separately, from two points of view, the interaction of angular velocity $(\dot{\theta})$ of the radius vector and radial velocity $(\dot{r})$. Then,

(*a*) The transverse component of the velocity is $r\,\dot{\theta}$, and r is changing at rate $\dot{r}$: thus, there is a transverse acceleration component $\dot{r}\,\dot{\theta}$.

(*b*) The radial component of velocity is $\dot{r}$, and its direction is changing at rate $\dot{\theta}$: thus, there is an acceleration component $\dot{r}\,\dot{\theta}$, acting normally to the velocity component concerned, i.e., transversely to the radius vector.

The Coriolis acceleration is the sum of these two components, i.e., $2\,\dot{r}\,\dot{\theta}$.

Yours faithfully,
J. D. RICHARD.

Lockington Hall, Derby.
25 April, 1958.

Plant and Equipment

NEW FILMING AND PROJECTION TECHNIQUE

Todd-AO at London's Dominion Theatre

When the film " South Pacific " opened in London last week at the Dominion theatre—and this week at the Gaumont, Manchester—British picture-goers were able, for the first time, to sample the film industry's latest development in " audience participation " techniques, the Todd-AO process, which sets out to bring to the screen greater realism both in sound and vision—and to achieve this using a single film strip. As carried out at the Dominion theatre, Todd-AO has ensured for every member of the audience a well-defined picture and " hi-fi " stereophonic reproduction, but whether or not near-perfect visual and aural representation can justify a claim, such as the sponsors make, that " You are in the show with Todd-AO " is an aesthetic and psychological question beyond the scope of this article, which is concerned with the installation at the Dominion theatre.

Developed by the American Optical Company on lines envisaged by the late Michael Todd, the system achieves its remarkable results by a new type of camera capable of recording action over a very wide angle, using 65 mm negative and a system of interchangeable lenses; by a new type of projector for the 70 mm positive film, on which are incorporated six magnetic sound tracks; and a 50 ft wide highly-curved screen, of aspect ratio 2·2 : 1, with a Perlux high-reflectance surface which reflects light brilliantly over the whole colour range with complete fidelity. The Todd-AO picture frame is not only wider than the conventional 35 mm frame—it is also deeper, and affords 3½ times the photographic area of the standard 35 mm film. When projected, the correspondingly reduced magnification results in a sharper and more stable picture on the screen. To give near-horizontal projection on to the wide curved screen, a new projection room specially for the Todd-AO apparatus has been installed in the centre of the rear stalls at the Dominion theatre. The installation is prefabricated and can be readily dismantled and re-erected, within one week, in any required theatre. The sectional, soundproof and fireproof room was designed and made by Sound Control Limited, Colneside Works, West Drayton, Middlesex (they are also making a similar type of projection room for another new screen technique, Cinemiracle, which will be introduced at the Odeon, Tottenham Court Road, London, on 14 May in the film " Windjammer ")

The Dominion projection room measures 27 ft 4 in long by 14 ft 8 in wide, and slopes from 12 ft 6 in at the front to 9 ft 9 in at the rear. The outer skin comprises steel and asbestos panels secured to a structural steel framework. An inner floating shell is completely isolated from the outer skin, and from the fabric of the theatre and the projectors themselves. The projectors are rigidly mounted on a heavy steel framework secured direct to the concrete floor of the auditorium and are isolated from the remaining projection room floor. The cavity between the inner and outer shells is completely sealed off and is lined on one side with an acoustic absorbent. The projection port face of the outer skin is also treated with an acoustic absorbent to obviate the danger of " long path " reflections to the front of the auditorium.

The floating floor is 1¼ in maple wood surfaced with ¼ in industrial lino, upon which the inner cabinet is built; it is supported by five mountings in which rubber is bonded in shear to metal blocks. From this sectional wooden floor—no panel of which exceeds 2 cwt to facilitate handling—the inner walls and ceiling are constructed of rigid sections incorporating both a sound barrier

Fig. 1 (left) Inside the new sound-proof prefabricated projection booth at the Dominion theatre, showing the two Philips Todd-AO projectors.

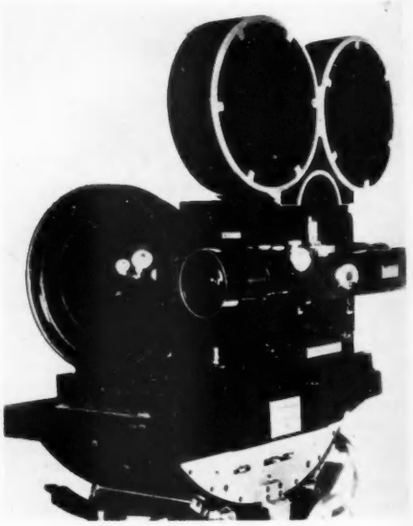


Fig. 2 (below) The Todd-AO camera, which takes 65 mm negative, and incorporates a "Bug-eye" lens giving a 128° field of view.

and sound-absorbent lining passing into the projection room. The gap between the inner and outer skins is maintained at 2 to 3 in and by using two sound-resistant doors and an acoustically " dead " lobby a sound lock is produced. Projection and observation ports are double-glazed with ¾ in plate glass—optical glass being used for projection ports.

Taking account of the rake (or slope) of the auditorium floor and of the required wide projection angles of the new process were added complications. Circuits Management Association engineers arranged for high-fidelity tape recordings and technical data of the Todd-AO equipment to be flown from Holland for the acoustic engineers at Sound Control Limited to work with. An internal maximum sound level of 86 decibels was assumed for all calculations. Recordings and sound spectra obtained from actual working of the two projection rooms justify all theoretical calculations and will provide valuable data for other applications.

The projection room in the Dominion theatre accommodates the two Todd-AO 70 mm projectors, and for the film " South Pacific " it employs six high-fidelity soundtracks. Other equipment installed includes free-standing six-channel amplifiers with spares, fader units, the special effects cabinet, film storage and rewind benches and non-synchronous equipment.

BUG-EYE LENS

Turning now to the optical and sound equipment: the heart of the Todd-AO technique is, naturally, the camera. Though designed to take the increased width of a 65 mm negative, it is only slightly wider and a few pounds heavier than the conventional 35 mm camera. The movement is of a double eccentric and link type, and is notable for its extremely quiet running. Normally running at 30 frames per second, the Todd-AO camera can also run at the standard 24 frames per second. A high-speed camera is also available which will run up to 90 frames per second for special-effects photography.

The camera is equipped with a wide-angle " Bug-eye " lens which can sweep and record fully a 128° view. Also, it will accept three other lenses, 64°, 48° and 37°, designed to be interchangeable, thus eliminating the need for additional cameras for each scene set-up and assuring a full cycle of filming without interruption.

The Todd-AO projector—developed and manufactured by the Philips Company, Eindhoven, Holland, in co-operation with the American Optical Company—possesses unusual flexibility in its ability to accommodate a wide variety of modern film techniques. The projector is designed to take 70 mm film, but it will handle other film processes, such as CinemaScope, VistaVision, etc., with minor adjustments to the mechanism that can be effected within minutes. Its rugged construction permits a steady picture at the high speed of the Todd-AO film as it passes through the picture gate at over 111·6 ft per minute.

An unusual feature of the design is that all the mechanism, including the magnetic and optical sound heads, is built into the projector head, thus eliminating the possibility of errors due to unequal film pressure. Other interesting design points include a centrifugal switch to drop the dowser if the film speed is too low, a water-flow switch to cut off the arc if the cooling-water supply is interrupted, and stop switches on both sides of the projector base. The single-bladed conical shutter cuts twice for every frame and gives an efficiency of 54 per cent.

All sprockets and rollers are made of non-magnetic aluminium, stainless steel or nylon. The projector gate is made of Tantung—a hard wear-resistant metal alloy which does not become magnetised. As a result, the recurring problem of degaussing is almost eliminated. A focus-drift compensator automatically corrects any de-focusing due to dimensional changes in the lens elements resulting from the heating of the lens. It also compensates for the inherent shallow depth of focus of short focal-length lenses.

As the size of the film is large and the film speed higher than for normal projection, the spool boxes of the projector are much larger than those for 35 mm spools. They accept 3,100 ft of 70 mm film, which corresponds to a projection time of 22 minutes. The upper spool box is illuminated and equipped with time scales.

SUN BRIGHT ARC LAMP

The arc lamp in use with the Todd-AO projectors is the Mole Richardson, Gaumont-Kalee type 490 " High Power " arc lamp supplied by the G.B.-Kalee division of Rank Precision Industries Limited. Running at 130 amperes and incorporating its own water circulating system, this carbon-arc light source gives a white light of high brightness, filtered to remove the unwanted heat radiation. At wide film aperture, its output of light (14,000 lumens) is equivalent in brightness to that of the sun.

The amplifier and loudspeaker equipment was manufactured by Rank Precision Industries Limited. The magnetic head on the Philips projector is designed to pick up the magnetic sound track from either a six-track 70 mm film, or a four-track CinemaScope film. Six Gaumont-Kalee magnetic pre-amplifiers are installed for each projector and can be connected to accept the signal from the six-track 70 mm film, or four of them to accept the four sound tracks on CinemaScope film.

The output of these six pre-amplifiers is fed to a main volume control unit which incorporates a change-over switch to change over the sound from one projector to the other; a system selector switch which selects six-track magnetic, four-track magnetic or single-track optical channels; and a five-gang volume control regulating the signal level to the five power amplifiers feeding the stage loudspeakers. The remaining track, which is the effects channel, is fed to a separate volume control and amplifier equipment that feeds the effects or ambient loudspeakers.

INSTRUMENTATION AND CONTROL ON SHOW

Concluded from page 489

Continuing our description of some of the exhibits at the Instruments, Electronics and Automation Exhibition, which concluded at Olympia last Friday, we return to the stand of the Ministry of Supply for another look at developments in automatically-controlled machine tools. Here, the Ministry were featuring details of a new Fairey-Ferranti three-dimensional programme-controlled high-speed contour-milling machine, shown in Fig. 3. Designed for producing large integrally-formed aircraft structural parts from rolled stretched stabilised light-alloy stock, the machine was made to the specification of the Aircraft Production Development Branch by the Fairey Aviation Company Limited in conjunction with Ferranti Limited, who developed the electronic digital control system.

The machine has a worktable 28 ft by 8 ft and a machining capacity of 25 ft by 7 ft by 1 ft. The spindle speed is 6,000 r.p.m. and the maximum peripheral cutting speed 12,000 ft per min. The traverse speed is 100 in per min. A range of 10 to 100 h.p. machining heads will cut metal at the rate of 4 to 7 cu. in per h.p. per minute. The 100 h.p. head is designed to remove about ½ cwt of metal per minute. Swarf collection is by endless belt. A high degree of surface finish is achieved.

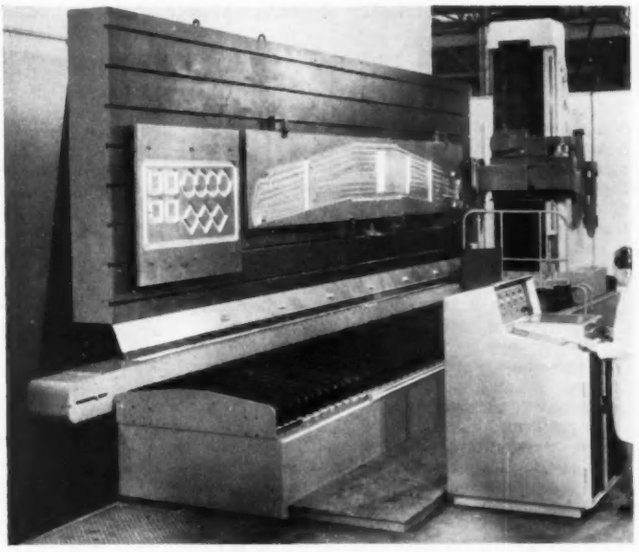


Fig. 3 Fairey-Ferranti programme-controlled three-dimensional miller.

The electronic digital control system is supplied with an optical grating having graduations at 500 lines per in, commensurate with the input signal rate for machining light alloy. Electro-hydraulic servo-mechanisms are provided to give 2½ h.p. at each slideway system. To provide a response system which would accept the input signal with close compliance, linear hydrostatic bearings were developed for the slideways of the three co-ordinate axes. This method of supporting loads reduces friction to that required to shear the pressurised oil film. The safety interlock system actuated by the error signal operates if the sum of the errors on the three axes exceeds 0·008 in, stopping the machine and thus avoiding scrap. For machining steel an interchangeable gearbox is provided. Gratings can be provided up to 5,000 lines per in for the slower speeds associated with cutting this metal.

Also on view on the Ministry of Supply stand was the three-dimensional inspection system for use in conjunction with tape-controlled machine tool systems, developed by the Ministry's Inspectorate of Electrical and Mechanical Engineering. This consists of substituting for the cutting tool in the tape-controlled machine tool,

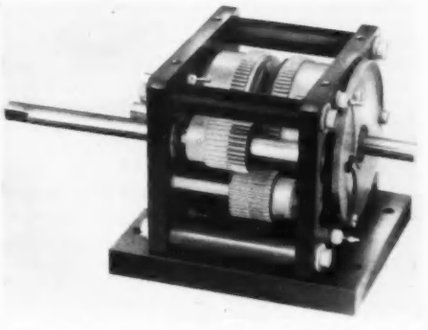


Fig. 4 Bi-directional high-torque clutch. Air Trainers Link Limited.

Continuing Plant and Equipment

a measuring head capable of indicating movement in any of the three co-ordinates; this makes possible speedy continuous and automatic measurement of workpieces. Among the advantages of this system of checking are that one machine can be used to check a variety of components simply by changing the tape; and similarly, modifications can be quickly embodied by supplying a new tape, in contrast to the time taken to modify existing gauges or to provide new ones.

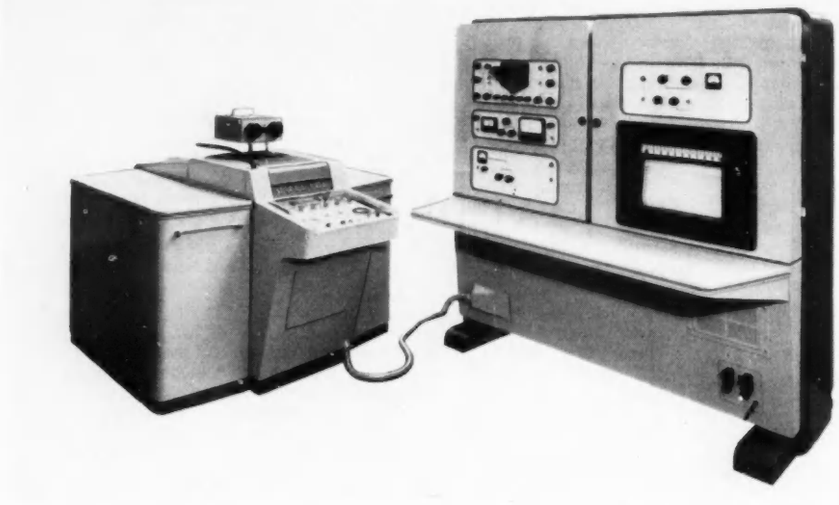


Fig. 5 Nuclear magnetic resonance equipment. Mullard Limited.

BI-DIRECTIONAL HIGH-TORQUE CLUTCH

Among the many developments in servo components on view, Air Trainers Link Limited showed an interesting new bi-directional electro-magnetic clutch, designed for use as a low-inertia high-torque servo drive where the required accelerations are greater than those normally available from an electric motor.

The electro-magnetic clutch is shown in Fig. 4 with the dust cover removed. Two identical diaphragm-supported clutch plates of magnetic material are mounted on the output shaft. Opposite each plate, and concentric with the output shaft, is a drive member carrying a friction surface and forming part of a magnetic circuit. These drive members are rotated in opposite directions by reduction gears from a shaft positioned alongside, the input shaft being driven by a constant speed motor. The control coils of the magnetic circuit, directly energised by a direct-current amplifier, are static, the magnetic flux being transmitted to the drive members across a small air gap. Thus, the direction and speed of rotation of the output shaft can be controlled by energising the appropriate coil to attain the required drive torque. The unit is available with a direct-current tacho-generator directly attached to the clutch unit, and geared to run at three times output shaft speed. The performance figures, at 25 mA control coil current, are as follows: output torque, 2 lb-in; acceleration not less than 3,000 radians per sec per sec provided friction loading does not exceed 0·13 lb-in and inertia loading does not exceed 0·10 lb-in.

NUCLEAR MAGNETIC RESONANCE EQUIPMENT

A chemical research tool that is expected to find increasing application in the quality control of industrial processing plant is nuclear magnetic resonance spectrometry—a non-destructive means of studying molecular structure by measuring the magnetic properties of the atomic nuclei comprising the molecule. Two firms were showing new N.M.R. spectrometers—Mullard Limited and the Fairey Aviation Company Limited.

The Mullard spectrometer consists of (i) a large controlled-temperature Ticonal permanent magnet, in the field of which a spinning specimen is located by a micro-manipulator; (ii) electronic apparatus for sweeping the field through the required range; and (iii) means of observing and recording graphically the nuclear magnetic resonance spectrum. The nominal field strength of the magnet is 7,500 gauss. Primarily, the equipment is designed for studying proton resonance, but it can be adapted for work with other nuclei. Important features are the high degree of uniformity of the magnetic field and high overall stability. A typical field uniformity is of the order of 1 part in 10^7 to 10^8 and the spectrometer is therefore capable of recording the fine structure of the ethyl-alcohol spectrum. Operation of the equipment is based on the Purcell absorption technique, using a single coil. This allows the probe used for introducing the specimen into the field to be of very simple design, and consequently affords great flexibility in varying the temperature of the specimen. It is shown in Fig. 5.

The prototype Fairey N.M.R. spectrometer on view has been designed to give a resolution sufficiently high to show chemical shift. The resolution, which is of the order of 2 to 3 milli-gauss (in a field of 5,000 gauss) has been achieved with a comparatively small permanent magnet. The electronic circuitry has been reduced to a minimum, and simplicity of operation has been a primary design consideration.

No special equipment is required to contain the sample under investigation other than a standard delivery tube, and this in turn is simply positioned in the probe. A large tuning dial is engraved in terms of the appropriate elements and tuning indicated on a meter. The spectrometer output is graphically presented on a pen recorder.

FLAME SPECTROPHOTOMETER

Another research tool for which its makers see wide uses for routine quality control in the processing industries—non-ferrous metallurgy, glass and ceramics, phosphates, dyestuffs, rubber and petroleum—is a flame spectrophotometer recently put into production by Unicam Instruments Limited for the rapid and accurate determination of metals in solution.

The instrument (Fig. 6) consists of a burner (for propane or acetylene) fed with an air supply (conveniently derived from a small compressor) in which the sample material has been finely dispersed by a concentric-jet atomiser. Light from the burner, which is very stable, is passed through a silica prism monochromator of high light-gathering power and on to a photomultiplier or photocell via a 100 c/s chopper. The detector output is amplified and synchronously rectified, and the resulting signal displayed as a direct reading of emission-line intensity on a spot galvanometer which has an open scale and high speed of response. An alternative signal outlet, suitable for operating standard types of self-balancing potentiometric recorder, is also provided. The instrument is constructed with the monochromator in an upper compartment and electronics below, the atomiser and flame controls being in a separate compartment at one end. The power supply and compressor, if used, are external.

NON-DESTRUCTIVE TESTING

For detecting flaws and corrosion in steam-condenser, heat-exchanger and other metal tubes of low magnetic permeability, the Sperry Gyroscope Company, Limited, demonstrated the Introview detector that they are making under

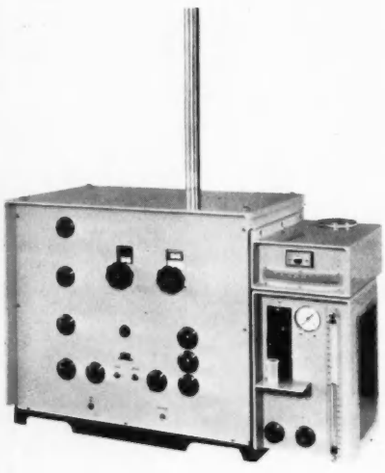


Fig. 6 (above) Flame spectrophotometer. Unicam Instruments Limited.

Fig. 7 (right) Flaw and corrosion detector. Sperry Gyroscope Company Limited.

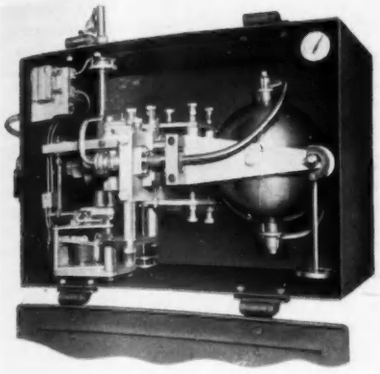


Fig. 8 (left) Transmitting liquid-density meter. Rotameter Manufacturing Company Limited.

Fig. 9 (right) Three-term electronic process controller. Evershed and Vignoles Limited.

licence from Imperial Chemical Industries Limited. Operating on the inductive principal, it comprises a chart recorder unit and a probe, containing two coils, which is drawn through the tube being inspected by a small electrically operated winch (shown in the background of Fig. 7, behind the probe and its cable). When the probe passes over a flawed or corroded portion of the tube, the absence of metal alters the electrical characteristics and shows up on the chart record—seen on the right of the illustration. On the left is seen the power pack.

Non-destructive testing of a different category —the stroboscopic X-ray examination of critical components of a vibrating assembly—was demonstrated by Philips Electrical Limited. The system uses standard X-ray apparatus, an image intensifier, and a closed-circuit television link which permits the range of conventional X-ray installations to be applied to the inspection of vibration phenomena over a side range of frequencies.

PHOTO TRANSISTOR CONTROLLERS AND RELAYS

New photo-transistor process controllers shown by Kelvin and Hughes (Industrial) Limited include a three-position temperature controller for maintaining controlled conditions within very close limits—of interest, for example, to the plastics industries. The instrument has two separate control actions, each operating a single-pole change-over switch. The two " set " points are independently adjustable relative to one another over a band width from zero to 10 per cent of full scale.

Also on view is a boiler pressure controller incorporating a photo-transistor circuit designed for the automatic regulation of oil burners on shell-type boilers. The controller is of the proportional action type which regulates both the oil and the air supplies through an electric positioning motor, thus maintaining constant steam pressure and optimum fuel/air ratios under varying load conditions.

Photo-transistor relays (Magister) for use instead of mechanical limit switches, suitable for applications such as counting, level control, warning devices, sequence checking and sorting, etc., were displayed by Metropolitan-Vickers Electrical Company Limited. The equipment consists of two small units—a lamp box and a receiver. The lamp box contains a transformer supplying a pre-focused lamp, from which the light passes through a lens to produce a parallel beam: the light beam is directed on to the receiver unit, where it is focused by a lens on to the photo-transistor. The output of the photo-transistor energises a Metrovick Fluxetter flux-resetting magnetic amplifier, which controls a relay having changeover contacts. The relay operates when the light beam is broken.

Also on view on Metropolitan-Vickers' stand was a central monitoring and control system for an oil storage and distribution installation. This system comprises primary measuring elements which present the value of the measured quantity (temperature, pressure or level) in electrical analogue form. The analogue output of the primary element is convered to a number in a binary digital register, and the number in each register is transmitted to a corresponding register at the central control point. The frequency with which any individual condition is transmitted may be arranged to suit the operational requirements of the particular plant. The contents of the register at the control point is displayed as a decimal number on " In Line " indicators. The same information may be used for automatic control of the installation.

FLUID MEASUREMENT

In the field of fluid measurement and control, the Rotameter Manufacturing Company Limited showed three types of transmitting rotameters and a new transmitting density meter for clean liquids. Developed in the first place for use in aircraft engine test bed fuel lines, this latter instrument has wide applications and is arousing the interest of the food-processing industries; it has also been successfully used for measuring the amount of aeration in lubricating oils. The liquid, fed through a spherical vessel, is continuously weighed on a pneumatic force balance, which detects changes in density and transmits a 3 to 15 lb per sq. in output signal linearly related to the density change. A minimum sensitivy of 0·03 gm/ml for full-scale deflection can be obtained, and working pressures up to 75 lb per sq. in gauge can be accommodated. The instrument is shown in Fig. 8.

In the Type 400 transmitting Rotameter the float contains a magnet which provides a magnetic coupling to an indicating instrument, and which is also linked to a pneumatic system giving a 3 to 15 lb per sq. in air output signal linearly related to the fluid flow. In the instrument on view at Olympia, the output signal is used to operate a recorder. Similar in principle is the Type 300 instrument, except that the magnetic coupling is linked to a co-axial electronic repeater which generates a direct-current signal linearly related to fluid flow; this type of instrument is suitable for computer control.

A different principle is adopted in the Type 640 Rotameter, which is suitable for very low rates of flow, from 0·025 to 0·25 litres per minute. In this instrument, a small iron armature is embedded in the float, and a differential transformer is wound on the metering tube. The primary is energised from an arc-supply. The secondary is centre-tapped so that the ratio of the E.M.F.s induced in each half is a function of the position of the iron armature and, therefore, of the rate of flow.

THREE-TERM CONTROLLER

Evershed and Vignoles Limited showed their new Mark IV three-term electronic process controller, the most interesting feature of which is that there is no interaction between the proportionally integral and derivative control terms. This, it is claimed, permits exceptional use of the derivative term—it may be possible, in fact, to use derivative control with a phase advance of at least 70° to cancel part of the plant lag, with beneficial effect on the stability of the system. It is shown in Fig. 9.

The controller is designed to operate in conjunction with electronic repeater transmitters which provide a " measured value " d.c. signal proportional to the physical variable being measured. The " measured value " signal is compared with a manually adjustable " desired value " current, and through electronic circuitry a controller output is developed which contains proportional integral and derivative components. There are no moving parts. The output signal, a direct current in the 0-15 mA range, may be used to operate electro-mechanical, electro-hydraulic, or electro-pneumatic process regulating mechanisms. Although, the makers state, the instrument does not require regular maintenance, it is constructed to facilitate maintenance and testing in-situ, with plug-in etched foil printed circuit boards containing all the valves and components. Only the thermionic valves are employed, and they are used merely as infinitely variable resistance.

HIGH-FREQUENCY CHART RECORDER

An unusual type of high-fidelity chart recording unit, the Mingograf 230B, made by Elema-Schönander, Sweden, was shown on the stand of their agents Sierex Limited. In this system, a jet of coloured writing fluid is directed on to the recording chart paper by a tiny nozzle which is attached to the loop of a galvanometer in such a way that when a current flows in the loop, the nozzle, and the capillary which feeds it, deflects through a small angle sensibly proportional to the current flowing in the galvanometer loop. By this means, and with the aid of compensation circuits, satisfactory chart records of oscillations as high as 1,000 cycles per second can be obtained. The fluid is pumped to the nozzle by a membrane pump activated simultaneously with the paper transport; the paper speed is adjustable from 5 to 200 mm per sec.

Finally, a brief reference to the words of the chairman of the Exhibition Committee, Mr. E. W. Semmens, at the opening luncheon: to maintain the present success of the British instruments and electronics industries, manufacturers should be prepared to give better service and keep to delivery dates—" the world will not use automation unless we can produce the equipment *how* they want it—and *when* they want it." Mr. Semmens also called for greater attention to publicity in the sense of keeping the rest of the world informed—and in respect of information, we should like to add our own modest plea—that those who are manning the stands at exhibitions should at least take the trouble to read the official catalogue so that they are aware of what products they are supposed to be demonstrating.

The addresses of the firms mentioned are: Fairey Aviation Company Limited, 24 Bruton Street, London, W.1; Ferranti Limited Crew Toll, Ferry Road, Edinburgh; Air Trainers Link Limited, Bicester Road, Aylesbury, Buckinghamshire; Mullard Limited, Torrington Place, London, W.C.1; Unicam Instruments Limited, Arbury Works, Cambridge; Sperry Gyroscope Company Limited, Great West Road, Brentford, Middlesex; Kelvin and Hughes (Industrial) Limited, 2 Caxton Street, London, S.W.1; Metropolitan-Vickers Electrical Company Limited, Trafford Park, Manchester 17; Rotameter Manufacturing Company Limited, 330 Purley Way, Croydon, Surrey; Evershed and Vignoles Limited, Acton Lane Works, Chiswick, London, W.4; Sierex Limited, 241 Tottenham Court Road, London, W.1.

In Parliament

EMIGRATION OF ENGINEERS

Reference was made by Mr. Frederick Willey (Labour) in the House of Commons last week to the concern expressed in some quarters regarding the emigration overseas of British engineers and scientists. He asked Mr. Harmar Nicholls, the Parliamentary Secretary to the Ministry of Works, to state what recent information the Government had received on this subject. Another speaker, Mr. Arthur Woodburn (Labour), pointed out that a great deal of the loss of professional manpower from that cause, occurred before the men entered employment. He emphasised the present position under which many large concerns were waiting on university doorsteps and enlisting personnel even before they had finished their examinations.

Mr. Nicholls, speaking in his capacity as the representative in the Commons of the Lord President of the Council, said that further information about the emigration of qualified engineers and scientists had been obtained from a number of leading firms, in response to a request from the Committee on Scientific Manpower. The investigation was still continuing and the committee hoped to obtain information from university professors of engineering and from the professional institutions.

Most of the firms which had been approached during the inquiry were of the opinion that their emigration losses were not excessive in relation to the size of their technical staffs and to their annual intake of engineers and scientists. He could not give details as the information had been supplied in confidence.

DISTRIBUTION OF ENGINEERS

Later, Mr. Willey asked what inquiries were at present being conducted by the Government to ascertain how research scientists were distributed in British industry. He was told by Mr. Harmar Nicholls that it was planned to carry out a second inquiry into the numbers of qualified engineers and scientists employed in Britain, similar in scope to the inquiry made in 1955-56.

He said it would be remembered that the results of the first inquiry had been published in the report of the Lord President of the Council entitled *Scientific and Engineering Manpower in Great Britain* [HMSO, Oct. '56, 1*s.* 6*d.*]. That report showed the distribution of these personnel according to the type of their employment as well as by industry and by qualification. In the new inquiry employers would again be asked to indicate the numbers of engineers and scientists who were mainly engaged on research and development. It had been felt by the Government that three years should elapse between the two investigations, and the second inquiry would accordingly be started in the coming autumn.

Other aspects of this matter brought out by Mr. Willey were that in view of the shortage of qualified engineers and scientists, it was important to see that they were employed in the right places, and that the Government's inquiries should be followed up with advice and assistance to these persons to go where they would be most influential.

COMPUTERS IN STEELWORKS

Several ways in which electronic computers can be used profitably in steelworks for production control have been successfully demonstrated by the British Iron and Steel Research Association, with the support of the Department of Scientific and Industrial Research. Examples of such uses of computers, Mr. Harmar Nicholls said, were to be found in the organisation of furnace repairs and in the calculation of the burden of blast furnaces. Interested member firms, he told Mr. Godfrey Lagden (Conservative) were investigating, jointly with the Association, the applications of these methods.

Asked by Mr. Lagden whether research was being undertaken into the allied subject of automation, Mr. Nicholls said it was. In that direction, too, the Association had had a number of successes. One which typified what was being done was a device for the automatic control of strip gauge. That mechanism resulted in a saving of rolled steel and had been developed at a time when such a saving was of very great importance to industry.

CO-OPERATION WITH EURATOM

Mr. Harold Macmillan, the Prime Minister, told the House that Britain was anxious to co-operate with Western European countries in atomic energy activities and that the Government would choose the form of co-operation which they believed to be best suited to the circumstances. Britain had bilateral agreements with five of the six Euratom countries and was studying the question of her future relationship with Euratom itself. He did not think that a joint working party between the United Kingdom Atomic Energy Authority and Euratom would help at the present stage.

It was pointed out by Mr. Roy Mason (Labour) that the British Government had no direct official link with Euratom at any level whatsoever, although, at the same time, the United States had formed a general working party with Euratom and had recognised that body diplomatically. Would it not be advisable, he asked, for the Government to take some positive steps in that direction, so as to safeguard this country's atomic energy prospects in Europe?

Mr. Macmillan agreed that such action was advisable and said that that was why Britain had entered into these bilateral agreements with all the countries, except Luxembourg, concerned in the Euratom organisation. There was also an association with Euratom under the Organisation for European Economic Co-operation, which had set up the European Nuclear Energy Agency: a body that included both Great Britain and the six Euratom countries. He would certainly investigate sympathetically the possibility of some further steps by which Britain's association with Euratom could be made more complete.

RATES EMBARRASS INSTITUTIONS

The difficulties which certain professional and charitable institutions are facing, owing to substantial increases in the rateable value of their premises under the Rating and Valuation (Miscellaneous Provisions) Act, 1955, were brought to the attention of the House by Major P. H. B. Wall (Conservative). He emphasised the position that, although it would be an exaggeration to use the word "extinction" in respect of such great national institutions as the English Speaking Union, even bodies of that importance were suffering a very real burden owing to the decision of the Courts that Section 8 of the 1955 Act did not apply to them. Small institutions, such as the Allied Circle, which had suffered an increase of some 300 per cent in its rates, had been placed in a disastrous situation.

On this matter, Mr. J. R. Bevins, the Parliamentary Secretary to the Ministry of Housing and Local Government, said that, while some institutions had had substantial increases in their rateable values and might not be entitled to relief under the provisions of the 1955 Act, the Minister of Housing had no power to abate a rate demand. A committee had been appointed in January under the chairmanship of Sir Fred Pritchard to advise the Minister on the rating of charitable bodies and similar institutions. He had no doubt that the committee would carry out their duties expeditiously and their report was awaited.

ISOTOPES FOR INDUSTRY

Mr. Roy Mason (Labour) asked the President of the Board of Trade to what extent his department ensured that British industry was kept informed of the various uses of radioisotopes. He also inquired to what extent there was liaison between his department and the United Kingdom Atomic Energy Authority on the new discoveries in this field, and how best such discoveries could be used. He suggested that consideration should be given to conducting a survey of all the industrial uses of radioisotopes, with a view to issuing a report. Sir David Eccles said that industrial uses for radioisotopes were widespread and increasing rapidly. The Board of Trade could not usefully add to what was being done already by the Atomic Energy Authority through their Industrial Advisory Service, their Isotope School and their publications, to assist the use of isotopes in British industry.

Diesel Crankcase Explosions

Dangers arising from explosions in the crankcases of diesel engines were referred to by Mr. Harold Gurden (Conservative). He was informed by Mr. Harmar Nicholls that, with the support of the DSIR., the British Internal Combustion Engine Research Association had carried out work on the basic causes of crankcase explosions in industrial engines. They had developed an improved flame trap to confine any explosion that might occur and so reduce the danger. These traps would be a protection to operators of diesel engines. The danger of burns to the users was reduced by the suppression of the discharge of flames through the valves, and a substantial measure of protection was achieved thereby.

Accounts of Electricity Boards

The view was expressed by Sir Alfred Bossom, Bt. (Conservative) that the North of Scotland Hydro-Electric Board and the South of Scotland Electricity Board should publish complete commercial accounts of their finances, showing full details of all moneys received and expended. On this matter, Mr. John Maclay, the Secretary of State for Scotland, said that, in accordance with the general directions which he had given to these boards, their reports included comprehensive accounts of their expenditure conforming to the best commercial standards. The reports referred to had already been presented to the House.

London Airport Extensions

Recommendations made by the Millbourn Committee for future developments at London Airport had been accepted, said Mr. Harold Watkinson, Minister of Transport. The next phase would include the construction of additional aircraft stands in the central terminal, for which tenders would be invited in May. This work would involve the laying-out of a new "acreage of concrete" for use by the big jets and turboprop aircraft which were now coming into service. That extension, it was hoped, would be followed immediately by work on a new passenger terminal building for long-distance operators, to take the place of the temporary buildings on the Bath Road. The Government wanted to have this new passenger building or, at any rate, a part of it, open within the next two or three years.

Underwater Cargo Vessels

Mr. Arthur Moyle (Labour) wanted to know what assistance was being given by the Government to advance the development of submersible means for the transportation of cargoes by sea, in view of the possibility which such methods gave of attaining higher speeds, coupled with greater scope for automatic control and increased safety from an aerial attack. Mr. T. G. D. Galbraith, the Civil Lord of the Admiralty said he understood that some industrial concerns in this country and elsewhere were interesting themselves in such schemes. His own committee, however, which were studying the problem of getting nuclear propulsion into merchant ships, were concentrating at present on the application of this form of propulsion to surface vessels: a project which, in his view, was more susceptible to early achievement.

Companies in the News

Giant Steps Forward

The report of the directors of Imperial Chemical Industries Limited on the group's activities in 1957 tells a story of continued and, in some fields, spectacular progress. ICI are now reaping the benefits of a capital expenditure of £305 million in the past ten years. It amounted to £67·7 million in 1957 and at the year end outstanding commitments amounted to £37·6 million. The year's expenditure on research amounted to £8·5 million, and on development, including technical services, £5 million. Investment in future products and better manufacturing processes thus amounted to £13·5 million, or 2·9 per cent of total sales.

These two items—capital investment and research—provide the key to the group's amazing progress since the war. Total sales to external customers on the home market amounted to £254·9 million (£243·7 in 1956) and to external customers overseas to £208 million (£191·6 million). The directors' comment, that these increased sales "derived to a considerable extent from the large capital sums which the company has spent since the war on extensions and the erection of new plants," is a clear enough indication that this growth, and the vitality and enterprise that lie behind it, was primarily a factor of investment in technical progress. The 22 per cent increase in manufacturing and trading profits, to £46·7 million—despite a number of adverse factors, such as the Suez crisis and a global increase of £10 million paid for raw material—suggest that there has been a substantial rise in productivity. Employees in the United Kingdom numbered 115,846 at the end of the year, only some 400 more than a year earlier. An interesting feature of the company's recruitment of qualified staff was that for the first time the number of engineers recruited was the same as the number of chemists. During the year, 417 scientists and engineers and 83 arts graduates joined the company. The group now employ 6,137 professionally qualified engineers and scientists and 2,296 non-technical staff in managerial positions.

In their brief review of the economic and industrial developments, the directors point out that towards the end of the year there were signs that "many customers were reducing stocks and that order books in some sections of industry were less full than they had been." They instanced a lesser pressure of demand on the iron and steel industries, reduced activity in the building trade and the industries which serve it, as well as a falling off in the demand for textiles. The year ended, they said, "with some feeling of uncertainty about trading prospects for 1958." Despite this, the group's sales in the home market in the fourth quarter were slightly higher than in the preceding quarters. The chairman's comments on the current position will be awaited with keen interest.

Machine Tools

Two companies in the machine tool industry, A. A. Jones and Shipman, of Leicester, and Clarkson (Engineers), of Nuneaton, find it difficult to predict the next year's results. Mr. F. C. Morris, chairman of Jones and Shipman, points out that they started 1958 with a backlog of orders lower than the previous year and that conditions are becoming very competitive indeed, particularly in export markets. Low commodity prices, chronic shortage of sterling (as in South America) and lack of credit at home are exercising a depressing influence on machine tool buyers. Under such conditions the company have the unpleasant prospect of keeping up their turnover at the expense of competitors. Last year trading profit fell back by about £39,000 to £462,000. A more substantial fall is likely to be registered this year. None the less, as Mr. Morris said in his report, they are a young and enthusiastic team and face the future with confidence. The need to fight hard for a living can have a most salutary effect, especially after a long period of unbroken sellers' market.

Mr. F. H. Clarkson described the past year as a difficult one, with increases in manufacturing costs and a general shortage of cash on the part of customers, which encouraged them to order in smaller quantities and to stock less. The fact that the company's turnover and profits actually went up—the latter by over £50,000 to £271,000—is doubtless explained by a general increase in engineering output in 1957 when most firms were working off their backlog of orders. It reached record levels and the consumption of milling cutters and drills was therefore very high.

Clarkson have formed a new subsidiary in Italy, Clarkson Italiana, S.p.A., to distribute their products from Milan. Their German factory is now in full production and the company will therefore have the initial advantage of having manufacturing facilities within countries forming the common market. Doubtless because of their good European coverage they feel that the free trade area would be "most beneficial."

German Electrical Company

AEG (Allgemeine Elektricitats-Gesellschaft), one of the largest manufacturers of electrical equipment and machinery anywhere, reported an increase during 1957 of 13 per cent in turnover, to DM 1,237 million, and of 7 per cent in employment, to 55,400. Export sales accounted for nearly a fifth of the company's total business and foreign orders booked during the year increased sharply and were the main reason for the improvement which took place. In the case of the home market, orders were less than deliveries.

A number of statements in the AEG report are of particular interest to British industry. The company are finding that international competition in foreign markets "remains strong," and that their own competitive position is being adversely affected by "the continuing rise in expenditure and by increased labour costs." The gradual rise of German wages to the levels prevailing in other countries is unmistakingly having its effect on their price structure (or profitability) with the prospects of an even greater relative increase in the future.

The group set up a central division to handle the training scheme of all their subsidiary companies, in view of the increasing importance of ensuring an adequate supply of skilled workers. At the end of September last year they employed nearly 800 trainees and 1,900 apprentices. Attention should be drawn, says the report, to "the growing proportion of foreign students, particularly from countries of the Middle East and Asia." This is becoming part and parcel of German industry's attack on marketing in underdeveloped countries.

Perhaps the most significant of the statements in the report referred to measures which were being taken "principally aimed at rationalising production and thus increasing the efficiency of the company's technical organisation as a whole." Absolute priority on available financial resources was being given to "the promotion of technical progress," including research and development but with the emphasis on technical organisation and methods. The product is being singled out for close study, to make it the most up to date and to make it cheaper to produce. Another main line of development that AEG are following lies in the provision of "technical consultative services for the company's clients." This advisory function is increasing in importance as products grow more complex and as new ones are put on to the market. The provision of electrical engineering rather than of a range of electrical machines and instruments is rapidly becoming the general approach being made by AEG.

Ship Owners

Exceedingly pessimistic views on the future of the shipping industry have recently been given by two of the foremost authorities in the world on the subject. Sir William Currie, chairman of the Peninsular and Oriental Steam Navigation Company, has told his shareholders that "the general position of cargo trades has deteriorated, particularly since the end of 1957" and that "at present there is little prospect of any improvement and if these conditions persist for very long it will be necessary to lay up ships." Mr. Stavros Niarchos, the head of the largest of the independent tanker operators, has said he is not optimistic "about any improvement before 1960." If there is no recovery of freight rates by then, "the situation will be serious."

On the problem of depressed freight rates, Mr. Niarchos pointed out that the oil companies were laying up their own tankers and running the ships they have on long charter; most of them do not anticipate rates to recover before 1960. Cancellation of orders for new ships and the scrapping of pre-war tonnage are more likely and more workable measures of freight stabilisation than the scheme put forward recently. It would in his view be a major error to boister up uneconomic tonnage: modern tankers would be penalised to support old tankers. It would also mean that speculating owners would not cancel any orders for ships to be delivered after 1960. He would therefore only consider a scheme to assist modern tonnage.

Both Sir William Currie and Mr. Niarchos had something to say on taxation and registration under flags of convenience. The incentives are less than they were, said Mr. Niarchos, for the cost of operating a British ship is often less than that of operating a "Pan-Hon-Lib" one and taxation of profits has now become largely irrelevant: "It is now a matter of not making losses rather than making profits." Sir William is much more concerned with the level of taxation in the United Kingdom, as might be expected. The Cunard Line have, indeed, postponed construction of their new 28,000 ton liner for the New York service. What has been called "the increasing competitive disadvantages of British shipping" are undoubtedly the most basic and important factor in the long-term prospects of our merchant fleet.

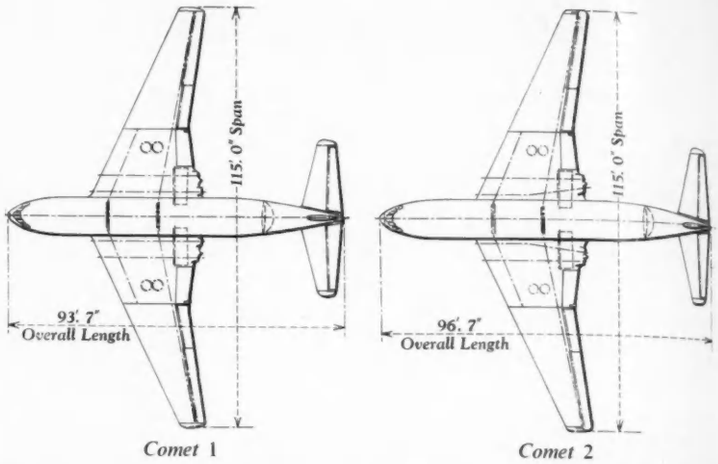
Shipbuilders

Under the heading of capital commitments, Sir William Currie said that P. & O. have not cancelled any of their orders for new tonnage, but that their building programme was not "inviolate" and certainly not unrelated to the likelihood of profitable employment for the ships. "We are," he said, "watching market trends and conditions very closely and if it should prove necessary to adjust our building programme we shall do so." Mr. Niarchos was much more definite: cancellations were inevitable, particularly for ships due to be delivered after 1960.

The remarks of Mr. E. J. Hunter, chairman of the Swan, Hunter and Wigham Richardson Group, in his annual report ignore the question of costs completely. Turnover in 1957 remained satisfactorily high, and although profits dipped about £½ million to £2·68 million, their level was good enough. The work in progress at the year end was over £16½ million and the order situation very good. It is comforting to read that Swan Hunter spent £2·1 million during the year on new plant and equipment, have commitments of £3·5 million more, and further substantial projects "either under active consideration or at the actual planning stage."

Special Article

THE COMET'S INTENSIVE DEVELOPMENT



Comet 1 *Comet* 2

Fig. 1 *The prototype Comet* 4 *airliner.*

THE prototype Comet 4 aeroplane has now made her first flight and it is only a matter of months before BOAC take delivery of the first of their fleet of 19. Early next year Comet commercial services should be in operation between the United Kingdom and Australia; and for some time to come the Comet will be the only fully developed jet airliner in service. It embodies modifications based on the most exhaustive technical analysis to which an aircraft has ever been subjected, as well as the refinements resulting from 7 million miles of commercial operating experience.

The Comet 4 series of aircraft embraces several versions—the Intercontinental 4, the larger-capacity Continental 4b, and the 4c which has the capacity of the 4b but approaches the Intercontinental version in range capabilities. The Intercontinental 4—the version for BOAC and, possibly, for Argentine Airlines—will be the first in service, and it is this 60/75 seat version that the prototype represents (Fig. 1). Briefly, the Intercontinental Comet, which BOAC will fly on their Australian, Far Eastern and Johannesburg services, is intended for routes on which the traffic density and the stage-lengths are moderate (up to 3,000 miles)—routes on which many of the airports have runway facilities inadequate for the economical operation of the larger, faster but inflexible American airliners.

The Comet 4b—of which six are on order for British European Airways, for delivery from mid-1959—is a short to medium-stage derivative of the Comet 4. It has a fuselage 6 ft 6 in longer to carry more payload (up to 100 passengers) and is intended for cruising at lower altitude; the resulting loss in fuel economy is more than balanced by the gain in true airspeed for the same limiting Mach number over stages up to 1,500 miles in length. On this variant, drag has been reduced and landing lift characteristics enhanced, by eliminating the wing-nacelle fuel tanks, which are not needed on short hauls; and the wing span is reduced by some 7 ft for structural reasons. Optional features on the Continental version, designed to cut down the turn-round time, are built-in passenger stairs and an auxiliary power unit, gas-turbine driven, for engine starting and powering the aircraft services on the ground.

The Comet 4c, which may be described as a high-capacity Intercontinental, has the body of the 4b and the wing and fuel capacity of the 4. No orders for this model have as yet been received.

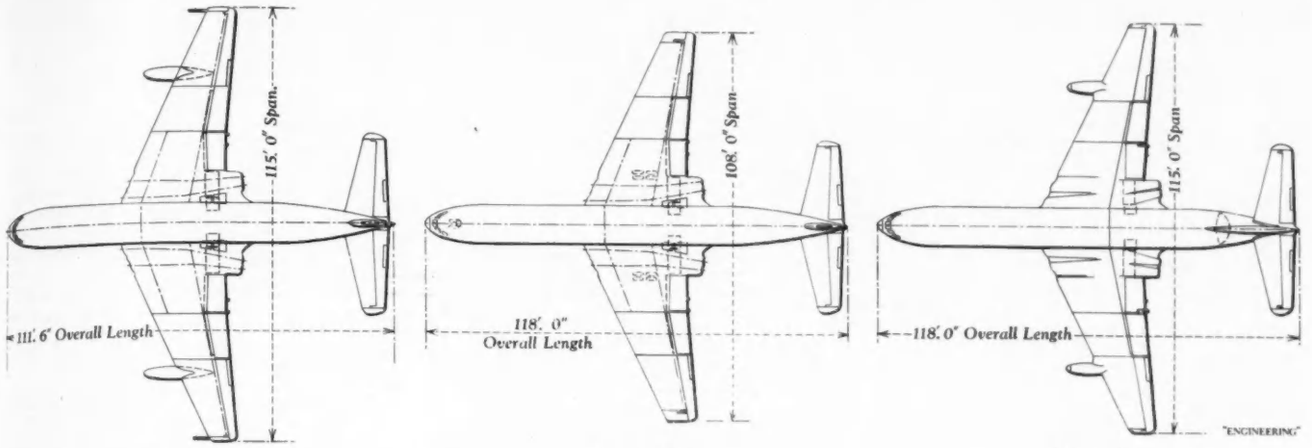
EVOLUTION

It is interesting to see how the Intercontinental Comet 4 has developed from the Comet 1. The latter aircraft had four Ghost turbojets each developing 5,000 lb static thrust, and had an all-up weight of 107,000 lb, with accommodation for 36 passengers. The Rolls-Royce RA29 Avons which power the Comet 4 each develop 10,500 lb thrust; the all-up weight is 156,000 lb and the passenger capacity is 60 first class or 76 tourist. Fig. 2 shows how the Comets have grown in dimension, and Fig. 3 shows the range/payload characteristics. The larger, faster Comet 4 (which normally cruises at about 500 m.p.h.) has been estimated to have an hourly revenue-earning potential of about 175 per cent of the Comet 1. Although the costs of aircraft have, like most commodities, risen appreciably since the Comet 1 was introduced six years ago, on balance it seems that the net profit resulting from Comet 4 operations will be appreciably higher than on the Comet 1's when they were in service.

From the operator's viewpoint, then, the Comet 4 is a better money-earner than the Comet 1, and a more versatile machine, both in seating arrangements and in performance, capable of covering distances twice as great, and, in BOAC's case, able to operate, generally, without limitation from all the airports on the routes concerned.

From the passenger's viewpoint, probably the main difference between the Comet 1 and the 4 is that on the latter, jet travel facilities will be available to the people who have to pay their own travel expenses and who cannot afford luxury fares. Whereas Comet 1 was designed only for first-class passengers, all the Comet 4 variants' cabins can be arranged to carry all tourist or all first class or mixed class traffic. The cabin is divided into two compartments, and in mixed-class operations the first class passengers would be seated forward, and the tourist passengers in the rear compartment. Each would have their own toilet and galley facilities—an arrangement designed less to perpetuate class distinctions than to make easier the task of the stewards and stewardesses.

Points that will strike the passenger who has



Comet 4 *Comet 4b* *Comet 4c*

Fig. 2 The Growth of the Comet series of Aeroplanes.

travelled on the earlier Comets are that, on long stages particularly, the journey time by Comet 4 is appreciably less—due partly to the higher cruising speed but mainly to the fact that refuelling stops are less frequent. For example, on the London to Johannesburg trip, the Comet 1 journey time was 21 hours 20 minutes. On the Comet 4, this can be cut to about 12 hours 40 minutes, if intermediate stops are made only at Cairo and Nairobi. (On the original Comet 1 services, stops were made—partly for traffic reasons—at Rome, Cairo, Khartoum, Entebbe and Livingstone before reaching Johannesburg.) The experienced jet-passenger will also notice that the cabin sound level is lower than on the original Comet, which itself set an altogether new standard in cabin acoustics. As is frequently the case, however, the air-distribution system in the cabin on the Comet 3 development aircraft called attention to its presence rather too audibly. By improved detail design in the ducting and ventilating outlets this minor irritation has, the manufacturers believe, been eliminated in the Comet 4 and its derivatives. The Avon engines themselves, too, are fitted with noise suppressors (Fig. 4), but these are less for the benefit of the air traveller than out of consideration for ground-borne dwellers near international airports.

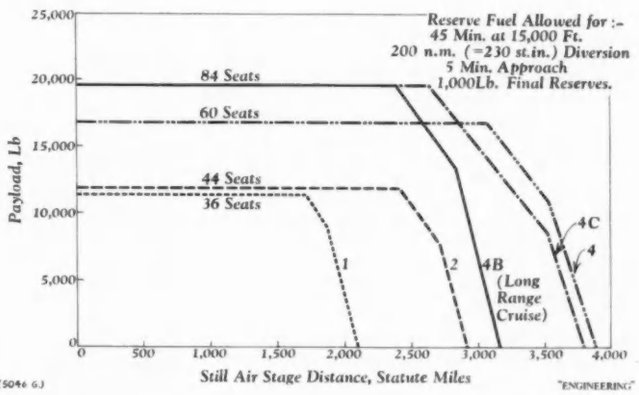


Fig. 3 Payload/range characteristics of Comet variants (first-class versions).

HANDLING

On the new Comets, the flight deck is more generously proportioned and is designed to accommodate a crew of five—two pilots, flight engineer, navigator and radio operator. The pilot will find in the Comet 4 a marked advance over the earlier aircraft, and indeed over most contemporary airliners. One of the lessons learned in commercial operation of the Comet 1 was that on the fast jet aircraft the crew had to think a long way ahead. The pilot's task, especially when coming in to a busy airport, is at best a complex one; and so, on the Comet 4 and its variants, every possible aid has been provided towards lightening his burden.

In addition the Comet 4 handles more sweetly. A rearward extension of the wing chord has given improved aileron control and bigger flaps. One characteristic of the Comet 1 could lead an insufficiently familiarised pilot into trouble—and in one case did result in a fatal accident: unlike most propeller-driven aircraft, which benefit from a ground cushioning effect, the lift of the Comet 1 was adversely affected near the ground. If the tail was pushed down too far and too early on the take-off ground run, it could happen that the aircraft would fail to attain flying speed. This tendency was overcome on the Comet 2's (now in service in R.A.F. Transport Command) and on the Comet 4 by substituting a drooped leading edge for the original symmetrical form.

All the controls of the Comet are power-operated by Lockheed Servodyne boosters, with a cable and push-pull linkage between the control column and the hydraulic booster. On the Comet 1, the frictional forces in the elevator circuit were considerably higher at cruising altitude, at which the ambient temperature might be as much as 100° C lower than that at take-off. To move the control column from the trimmed position an appreciable " break-out " force had to be applied—but once the initial friction and spring load were overcome the control forces were light. The break-out force has been substantially reduced on the Comet 2 and 4 by careful attention to minimising the friction at control pulleys and through pressure-cabin seals,

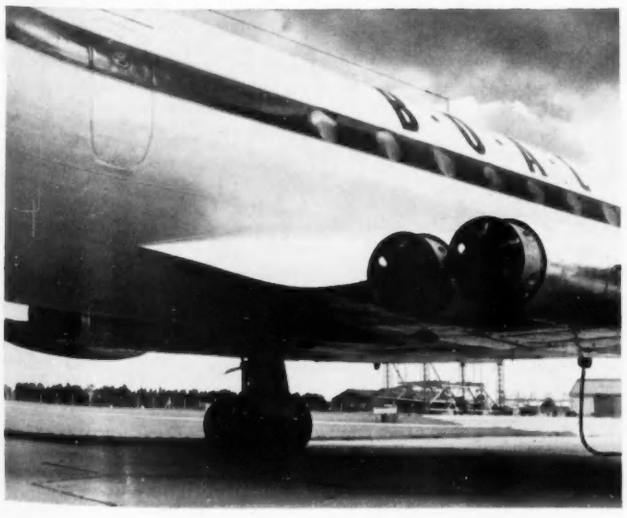


Fig. 4 (left) The Avons of the Comet 4 series will be fitted with noise suppressors, and thrust reversers (Fig. 5, right).

Continuing The Comet

etc., and by compensating the control cables for temperature effects. A two-speed gear has also been built into the elevator circuits so that now the control sensitivity is reduced at cruising speed while still remaining adequately sensitive at low speed. The Comet 4 elevator control circuit also incorporates a " Q-feel " device—that is, a mechanism for feeding back into the control column loads related to the air speed.

Other control refinements that have been incorporated, principally to ease the mental load on the pilot, include a stall-warning indicator (" stick-shaker ") which comes into action when the airspeed drops to 12 per cent above stalling speed; an automatic trim-change device in the elevator control circuit which audibly warns the pilot, and applies some nose-up trim, should the speed build up by more than 0·03-0·04 above the normal cruising Mach number; a " rudder limiter," operated by Q-feel, to prevent the pilot from inadvertently applying too much rudder angle during cruising flight; and automatic yaw dampers, mainly for facilitating approach in rough air conditions, both under manual control and under the autopilot.

A real step forward towards " automatic " flying has been made with the Smith SEP2 autopilot with which the Comet 4 is equipped. The SEP2, in addition to stabilising the aircraft, is fitted with speed and height locks, so that it can be set to climb or descend at constant airspeed, or to maintain a specified height; it can hold the aircraft on a given heading, monitored by the beam compass. It can be coupled to the navigational system to follow an airway pattern, or to the instrument landing system for a fully automatic approach. An essential complement to such a highly sophisticated flying aid is a completely independent monitoring system: this is provided by the Smiths Flight System instrumentation which integrates all the navigational and altitude information—hitherto displayed on a multiplicity of dials—and presents it to the pilot on two instruments only.

So far as handling the aircraft after touchdown is concerned, the Dunlop Maxaret anti-skid brakes with which the Comet 4 is equipped should ensure reasonably moderate landing runs, even on icy runways. There is, however, to be a tightening up of the British airworthiness performance requirements, which are under revision. To conform with the probable future standard on landing distances, thrust reversers for the Rolls-Royce Avons are being developed—they have been installed on the Comet 3 (Fig. 5)—and will be fitted to later aircraft of the series and, possibly, retrospectively.

LOW-STRESS STRUCTURE

The structure of the Comet 4 has, of course, been completely re-engineered although it is still based on the same conventional format of a two-spar wing and semi-monocoque fuselage. The design philosophy has, however, been re-orientated. To ensure a safe structural life of 30,000 hours, the stress level in the pressure cabin has been kept well down. The minimum skin thickness has been increased from 0·028 in to 0·04 in; and the windows and cut-outs have been redesigned, with carefully graded reinforcing members to avoid abrupt changes in stress level. A typical portion of the pressure cabin structure is shown in Fig. 6. The rear fuselage, tailplane and elevator have been strengthened against jet efflux fatigue. If, however, cracks were to occur due to damage in service, then, the new design philosophy postulates, they should propagate so slowly that they would be apparent to the inspection staff long before they could reach a dangerous magnitude.

A detailed and progressive fatigue test programme has been carried out to satisfy the designers that their objectives have been achieved. Allowing a scatter factor of 6 in these tests, the criterion of satisfactory behaviour has been that no cracks should develop in the test specimen before a minimum of 60,000 reversals (equivalent to some 180,000 hours of flying); and that any cracks subsequently appearing should not spread seriously before a further 60,000 reversals. The tests have progressed from small tests of skin lap joints, to repeated pressure tests on sections of fuselage panels including windows and cut-outs. Finally, three major fuselage sections were tested complete with doors, windows, etc.—the nose (118,000 pressure cycles without a crack), the rear portion (120,000 cycles without a crack), and the centre portion. The latter, including the wing section, which was also subjected to simulated gust loading, withstood 120,000 pressure cycles plus 2,880,000 wing gusts without failure.

Fig. 6 Typical portion of the pressure cabin structure.

Fig. 7 The specially-built 100 ton Amsler fatigue machine in which, among other items, the design of the wing-root joints was proved.

In the wing structure, the most interesting design change has been the abandonment of high-strength zinc-aluminium alloy, for the tension-loaded bottom skin and lower spar booms, in favour of a copper-aluminium alloy. This, although it has a lower ultimate strength, and therefore involves a weight penalty, is more reliable under fatigue loading than the zinc-based material. The wing-root joints have been extensively tested on a 100 ton Amsler fatigue machine specially made for de Havilland (Fig. 7), and by using closely-fitted bolts, selectively matched to the bolt-holes, with molybdenum disulphide as an anti-fretting agent, and controlling the bolt-tightening loads by the use of torque spanners, the test life of the wing-root joints was stepped up from 300,000 to 16,000,000 reversals unbroken. It should be mentioned that the gust loading under which the wing components were tested has been assessed from counting-accelerometer records, which register the actual accelerations experienced during flight together with speed and height, taken on a Comet 1 aircraft when they were in service.

The final structural test, now generally required for all British certificated airliners, has still to be carried out. The second prototype Comet 4 airframe complete is soon to undergo a pressure-fatigue test plus flight, gust and landing loads, in the water tank at Hatfield.

AIRWORTHINESS DEVELOPMENTS

In six years, thoughts on airworthiness generally have naturally developed, and standards have changed. A number of refinements directed to greater safety have therefore been built into the Comet 4—some to meet revised certification requirements and others simply to make the Comet a finer aeroplane. The Air Registration Board have, for example, revised their policy on emergency exits in favour of a small number of large exits rather than multiple small exits. Thus, the Comet has an additional emergency exit door at the aft end of the cabin opposite the main passenger door, and two window-type emergency exits, giving access to the wing, on each side of the cabin.

Various modifications to the control system which sweeten the handling of the aircraft have already been described. On all Comets duplicated and independent hydraulic boosters have always been provided for each control surface, operated by alternative hydraulic systems. An additional safeguard on the Comet 4 is that the mechanical linkage between the control column and the elevator and aileron boosters is also duplicated, and so too is the output linkage from the boosters to the elevator control-surface operating lever.

Basically, the Comet's hydraulic systems—there are four—remain unchanged: the " blue " system powered by the inboard engines, supplying the primary flying-control boosters; the secondary flying-control boosters being fed from the " green " system, which also supplies the undercarriage lowering gear, nosewheel steering, flaps, airbrakes and wheel brakes, and is powered by the outboard engines; the " yellow " system, providing electrically-powered emergency operation of the secondary flying-control boosters, and the " red " system for emergency operation of all the other services normally on the " green " line, and also electrically driven, with a stand-by handpump for undercarriage lowering. In the Comet 1 and 2, however, the green and yellow system shared a common return line—they are

now completely separate. On the Comet 1, much of the hydraulic and electrical equipment was grouped together in an underfloor compartment. On Comet 4, hydraulics and electrics are completely separated, with a freight hold between the two accessory compartments. Castor-based hydraulic oil is still the recommended fluid for the Comet's hydraulics, because so far, it is the only one compatible with the natural rubber seals and hoses that alone give the essential reliability under the wide range of ambient conditions that the jet aircraft operates in. However, a lot of development is in hand on synthetic rubbers that will stand up to a wide temperature range and will also take kindly to non-flam fluids.

Where essential services depend on electrical supply, the airworthiness authorities now require a split distribution system, and this has therefore been introduced into the Comet 4. Basically the power generation system is similar to, but of greater capacity than, the earlier one. The output from brushless engine-driven alternators is rectified to 24 V direct current for distribution —because fully developed electrical components in the United Kingdom are still mainly confined to 24 V d.c. There have been detailed modifications in the distribution system, too, in that de Havilland are increasingly favouring the adoption of American-type cables and terminal fittings in preference to British.

FIRE PRECAUTIONS

On the electrical equipment which is supplied by the component manufacturers, de Havilland have carried out extensive development work to improve their flameproof properties, including tests in their own explosion chamber. The manufacturers' specifications, they find, are less exacting than those of an aircraft constructor.

Although fire in the engines has never been a vice of the Comet, de Havilland have exerted especial efforts to prevent such occurrences in the Comet 4, mainly with a view to possible American purchasers who, brought up in the podded-turbojet tradition, tend to regard buried

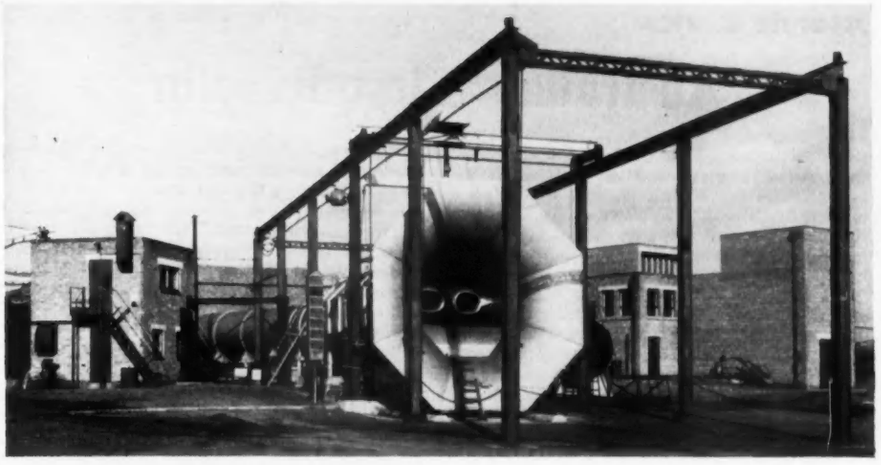


Fig. 8 The Comet 4 power plants installed in the Rolls-Royce fire tunnel.

" blow torches " with suspicion. Accordingly, all the hot zones are completely encased in stainless steel and titanium, and rigorously sealed against fuel leaks; the engine bays moreover are slightly pressurised to prevent fuel from being sucked in should a seal be defective. In the event of the alternator catching fire, its drive can be disconnected. The whole engine installation has been subjected to a test in the Rolls-Royce fire tunnel (Fig. 8). The fuel system, too, has been revised—an independent fuel feed to each engine is now provided. Except in the centre section, all the fuel tanks are integral with the wing structure. Vent outlets have been provided at the trailing edge to reduce a possible fire risk arising from fuel accumulating in the trailing edge, and improved blow-out valves protect the tanks from overload during pressure-fuelling operations.

Other changes include a higher standard of thermal de-icing to meet more stringent official requirements and to protect the intakes of the axial flow engines. This has presented no great difficulty since ample hot air for the system is available from the final stage of the Avon compressors; in fact to prevent overheating the wing ducts it is often necessary to mix in cold air—the mixing valve being thermostatically controlled.

The capacity of the cabin air conditioning system, which also comes off the final stage of the Avon compressors, has been increased for the larger aeroplane, with larger cold air units developed by de Havilland Propellers Limited, and modern pressure-control equipment.

These constitute the major engineering changes that have transformed the pioneer jet-transport machine into the highly groomed and versatile aircraft that is the Comet 4.

Fig. 9 The Comet 4 on her maiden flight.

Atomic Review

Australia's First Reactor

ON FRIDAY, 18 April, 1958 the Australian Atomic Energy Commission's research establishment at Lucas Heights, near Sydney, was opened by the Prime Minister of Australia, the Rt. Hon. R. G. Menzies, C.H., Q.C. The ceremony was marked by Mr. Menzies setting in operation Australia's first nuclear reactor " Hifar " (short for high-flux Australian reactor) and was attended by about 1,000 guests who included members of the Federal and State Parliaments as well as leaders of industry, commerce and the trade union movement.

These developments indicate a major step forward not only in the research and development programme for which the AAEC is responsible, but in the building up of the country's atomic energy industry. Construction of the laboratories and reactor commenced in October 1955. Meanwhile recruitment of the senior research staff had been mostly completed by mid-1955, who began work at the UKAEA research establishment, Harwell, pending completion of the laboratory facilities at Lucas Heights.

Fig. 1 The Australian Atomic Energy Commission's research station at Lucas Heights, Sydney, showing the research reactor Hifar in the background.

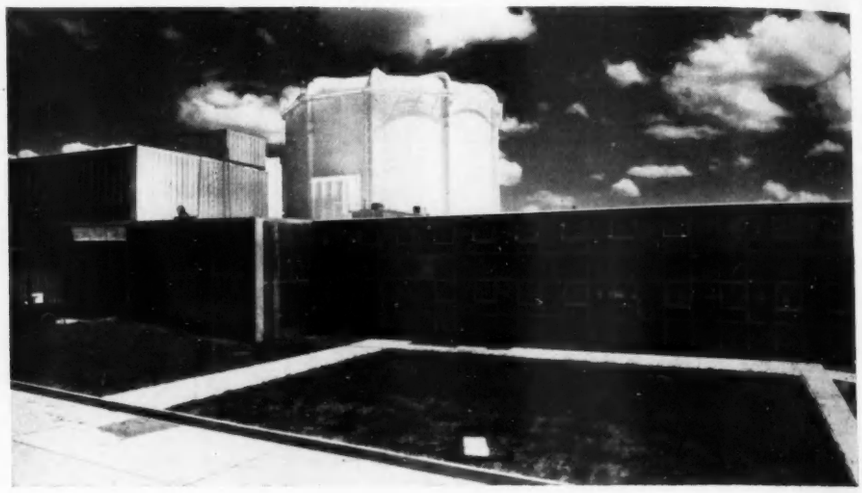
Subsequently, other scientific and assistant staff was engaged, bringing the total up to its present level of about 250. The first laboratory was occupied in December 1956 and by 1957 analytical services, workshops, design offices, electronic instrumentation, library, and health physics facilities had been provided. About this time work on the laboratories research programme was begun and developed as the Australian research teams returned from overseas.

The main objectives of research at Lucas Heights have been outlined by Mr. C. N. Watson-Munro, chief scientist, AAEC, as follows: (i) development of atomic power reactors suitable for Australian conditions; (ii) research into problems associated with power reactors such as fuel and moderator purification and fabrication, chemical processing of spent fuel elements, and treatment of radioactive waste products; (iii) to provide isotopes and radiation sources for which there are rapidly expanding uses in industry, agriculture, medicine and research; (iv) to provide a national centre with equipment and trained staff facilities to aid Australia in the development of the use of atomic power, and to provide any specialist advice or experimental facilities that may be necessary for this task; (v) to train scientists and technologists in atomic energy techniques.

Some of the considerations influencing the selection of reactor types for investigation were that the programme should not duplicate work already done on those reactor systems which had already been brought to an advanced state of development in the United Kingdom and the United States; that it could be undertaken on a co-operative basis with overseas countries, particularly the United Kingdom; it should be adaptable to the small power systems that Australia was likely to provide outside her larger industrial areas in New South Wales and Victoria; and that it should lead to reactor experiments and stages of development within the country's resources. It has therefore been decided to undertake research on two systems, the first and perhaps most promising is the high-temperature gas-cooled system using beryllium as a moderator, which has advantages over equivalent graphite systems for small electrical generating units in the range 5 to 20 MW; and the second, a liquid metal fuel reactor system using a sodium slurry as the coolant and fuel carrier.

Theoretical studies of these systems have been made and facilities were required which would provide the high flux densities for fuel element and sodium loop investigations (previously referred to in ENGRG., 10 Jan. '58, p. 41) required before prototypes based on these systems would be designed. With the commissioning of a high flux research reactor this work can now proceed.

Hifar was the first export order for a nuclear reactor from a British firm. The contracting firm was Head Wrightson Processes Limited, a subsidiary of Head Wrightson and Company, and the reactor is similar to the Dido nuclear reactor which has been in operation at the U.K. Atomic Energy Research Establishment, Harwell, since January 1957. Dido was designed by an AERE team in conjunction with the U.K. Ministry of Works and Head Wrightson Processes Limited, and these authorities provided the drawings and specifications of this reactor for use in building Hifar. Details of this type of reactor have been described previously, ENGRG., vol. 180, 1955, p. 836. Essentially it is a heavy water moderated reactor using highly enriched uranium 235 fuel with a maximum thermal flux of 10^{14} n/cm²-sec. It has been estimated that if natural uranium was used as fuel, the maximum flux density would have required a power output of 100 MW; this would have been extremely costly and inconvenient to dissipate. With enriched fuel the above high flux density is obtained with 10 MW which in the case of Hifar can be dissipated as heat energy by using heat exchangers to transfer the heat from heavy water to ordinary water from the Woronora river, which then loses its heat in cooling towers.



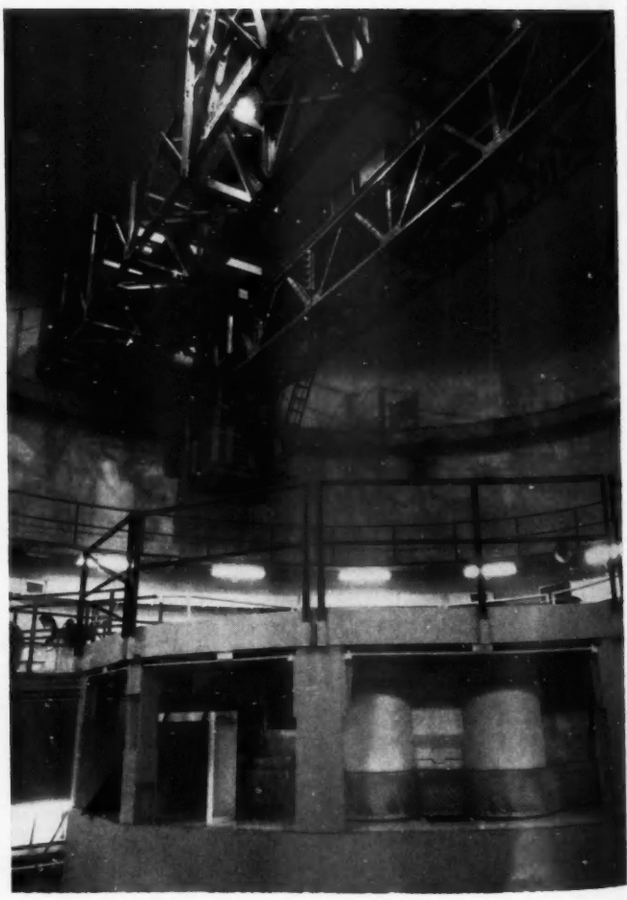


Fig. 2 An interior view showing Hifar, a heavy water moderated reactor fuelled with highly enriched uranium 235. The 5 ft thick concrete biological shield enclosing the graphite reflector around the aluminium tank containing the heavy water, and the fuel loading platform, are shown.

Preparation for Divergency Test

Construction of Hifar commenced in November 1955 and the reactor became divergent on 26 January, 1958. The steps taken to carry out a zero energy divergency test have been described by Mr. C. N. Watson-Munro (*Atomic Energy*, vol. 1, No. 2, pp. 3-8, March 1958)

from which the following information has been abstracted.

Before starting up the reactor it was necessary to ensure that the heavy water circuit was thoroughly clean, dry and free from leaks. The heavy water circuit is shown diagrammatically in Fig. 3. The moderator, heavy water operating between maximum temperature limits of about 44° C and 51° C, is circulated in a closed circuit through the 7 in diameter pipes (4), pumps (7), heat exchangers (6) and fuel elements (2). Two pumps and two heat exchangers are normally in operation.

The emergency pumps (8), operating from a guaranteed power supply, cope with fission product heat after reactor shut-down. The valve (11) acts as an emergency shut-down facility and can be opened quickly to dump the top 2 ft of moderator into the tank (10). Heavy water leaking past the valve (11) during normal operation is returned to the system by the transfer pump (13).

The moderator is kept at a constant level by one of the pumps (12) which continually circulates a few gallons per minute through the pipe (5) and storage vessel (9) into the main suction header. The ion exchanger (14) removes impurities from the heavy water.

Process testing was carried out with demineralised water to check that all pumps and equipment complied with specifications, and that all normal operations could be satisfactorily performed. The flows from the liquid level and transfer pumps were correctly adjusted by means of permanent restricting orifices in the delivery lines. Adjustments were also made to the various float switches, liquid level indicators, etc.

Pressure testing was carried out with demineralised water in the system. The reactor aluminium tank was isolated from the rest of the system and tested by filling with demineralised water and applying a nitrogen pressure of 9 lb per sq. in. The rest of the system was tested at 40-50 lb per sq. in by means of a small pump, pressure being held for 30 minutes on each section of the system.

The heavy water system was dried by the following method: hot filtered air was blown into the top of the reactor aluminium tank, and allowed to escape through all vent and drain points until free moisture was removed.

Various parts of the system were then isolated in turn, and hot air blown through until wet and dry bulb temperatures showed no measurable pick-up of water vapour. The general temperature in the heavy water plant room was maintained at approximately 80° F by means of eight 2½ kW fan-heater units.

The reactor aluminium tank and all instrument lines were then isolated, and purged with dry nitrogen until frost points of approximately −20° C were obtained. The remainder of the system was then vacuum dried until a final pressure of approximately 2 mm of mercury was maintained.

The vacuum was then broken by introducing dry nitrogen at the heavy water filling connection. When the pressure was slightly above atmospheric, all drains, vents and sections of piping were blown through separately. The reactor aluminium tank was then blown through via the piping system.

The system was then isolated for 12 hours and frost point readings taken, the final figures being: reactor aluminium tank, −11° C; rest of circuit (excluding main heavy water circulators), −20° C to −40° C. Total drying time was seven days.

The heavy water, supplied by the U.S. Atomic Energy Commission, was loaded into the storage vessel by displacing it from the transport drums with dry oxygen-free nitrogen. After one drum had been loaded a sample was taken from the storage vessel to ascertain if the vessel was clean enough to continue. Loading then continued until 8,000 kg had been put in.

Using the transfer pump, a small quantity of heavy water was then pumped into the reactor vessel and samples drawn from its drain line. These proved satisfactory; the reactor was filled to working level, and analyses were made again from the overflow pipe.

Prior to loading, all the fuel elements were inspected for cleanliness, major dimensions and axial alignment. There was no evidence of damage during transport from the UKAEA, although errors in alignment were greater than during manufacture. The fuel elements were assembled on the shielding plugs and the salvage couplings, flux measuring tubes and thermocouples were attached prior to loading.

Reactor Goes Critical

From measurements at Harwell in the Dimple and Dido reactors, it was estimated that Hifar would achieve criticality with eleven highly-enriched fuel elements. This proved correct.

For the approach to criticality the 2 in, 4 in and 6 in vertical thimbles were removed. However, to accommodate the boron trifluoride neutron counters, 1½ in diameter aluminium search tubes were placed in each of the 4V1 and 4V3 positions in the heavy water of the reactor core. The fine control rod was kept at the half-in position, and the main heavy water circulating pumps were not used.

To provide reasonable counting rates during the approach, a 10 millicurie radium beryllium neutron source was placed just below the bottom of the core region, at the centre of the 2-tan facility. While there were no fuel elements in the reactor, count rates (Co) on the various channels were noted with the coarse control arms fully out. Fuel elements were loaded one at a time, from the centre position outwards, keeping the core as compact as possible.

The first three elements were loaded without moving the control arms from the fully-out position. Count rates were noted on all channels as fuel elements were added, and plots were begun of Co/Cn against N, where Cn is the count rate with N fuel elements in the reactor.

The next four elements were loaded with the control arms partially inserted, and the eighth and succeeding elements with the control arms fully in. After loading each fuel element in these cases, the control arms were moved out in steps, Cn being recorded after each movement. Extrapolation of the above data to Co/Cn = O for each control arm position, enabled progressive predictions of a criticality to be made. Such a record, shown in Fig. 4, predicts the minimum number of fuel elements to be eleven, and the corresponding critical position of the coarse control arms to be approximately 35°. It should be noted that control arm positions are here given in terms of degrees up from the fully-in position, 56° below the horizontal.

The action of the trip circuits and the efficacy of the safety rods and coarse control arms were checked a number of times during the approach, in particular just before loading the last fuel element. A closer prediction of the critical control arm angle was given by plotting Co/Cn against the control arm angle with the last fuel element loaded, as illustrated in Fig. 5. Control arm movements were made progressively smaller as criticality was approached.

The predicted critical angle from all channels was now 37·5°. The control arms were slowly lifted from 37° to 37·8°, giving an exponential increase in flux with a doubling time of approximately 2½ minutes.

The radium-beryllium source was removed at this stage; it had no observable effect on the reactivity of the system. The power was levelled off at 1/20 watt, corresponding to a thermal flux of $1{\cdot}4 \times 10^6$ neutron per sq. cm per sec at the centre of the core, the steady control arm position for criticality being 37·5°.

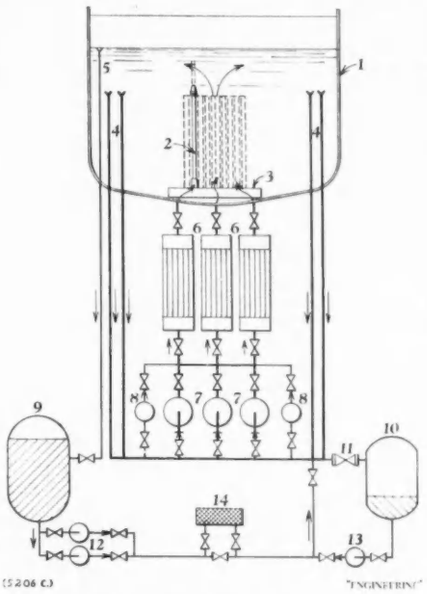


Fig. 3 Diagram showing heavy water system, pumping equipment and valves.

1. Aluminium tank
2. Fuel elements
3. Header plate
4. D_2O overflow pipes
5. D_2O level pipe
6. Heat exchangers
7. Main D_2O pumps
8. Emergency D_2O pumps
9. D_2O storage vessel
10. Partial dump tank
11. Partial dump valve
12. D_2O level pumps
13. Transfer pumps
14. Ion exchanger

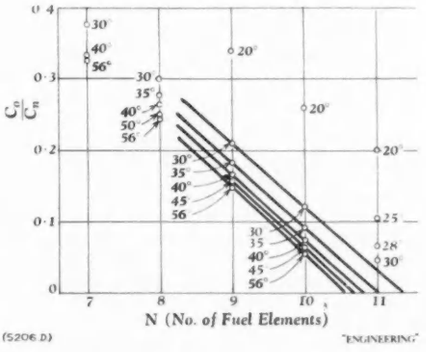


Fig. 4 Co/Cn against number of fuel elements (N) for channel 2 at various control arm positions.

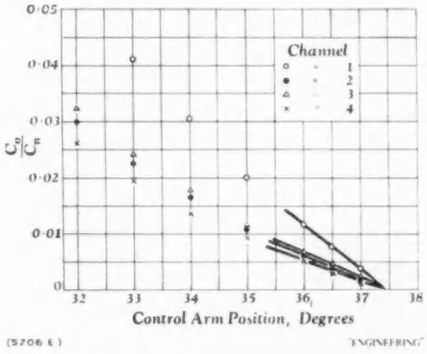


Fig. 5 Co/Cn against control arm position with eleven fuel elements loaded.

Other Facilities at Lucas Heights

The first stage of construction at Lucas Heights involves three main laboratory facilities. These are the research reactor and associated buildings such as the post-irradiation cells to enable extremely radioactive materials (multi-curie sources) to be handled and examined scientifically by remotely controlled machines and instruments; the chemistry-chemical engineering building with non-radioactive and active or so-called "hot" laboratories, the latter including a low-activity or "blue" laboratory, and a high-activity or "red" laboratory; the third facility is the metallurgical fabrication bay of what will be the metallurgy-engineering building, which will be equipped with rolling mills, hydraulic press, vacuum furnace, high frequency induction heating plant and other equipment.

The Human Element

"Theory and Practice"

The appointment of a new board of Governors by Faraday House Engineering College is announced, and with it there has come a statement about future policy. The College remains a private foundation answerable to the Ministry of Education only for its standard of efficiency. At a time when a great expansion of technical training is going on it is therefore in a unique position to prove that independence means both flexibility and imagination. Its motto is "Theory and Practice" and there should be ample scope for proving the interconnection of these two ideas in the years that now lie ahead.

The college was founded in 1889 to educate engineers in the expanding electrical supply industry. It was early connected with the development of what is now called the "sandwich" educational system for technical students. The college now proposes to broaden its activities. Instead of catering almost entirely for electrical power engineers it will include in its curriculum training for both the mechanical and physical sciences. In electrical engineering the significant move is being made to include courses on light engineering subjects. Such a broadening of interests for an independent organisation is both an opportunity and a challenge.

Making Labour Flexible

At the end of last week the House of Commons hear Mr. Macleod, Minister of Labour, express an optimistic view of the unemployment situation. The main problem is the relatively large proportion of unemployed in some industrial areas, most of them in Scotland, Wales and Northern Ireland. There has been a further small increase overall, but Mr. Macleod did not think it would raise the April figure above 2 per cent of the working population. There is, however, a tendency for unemployment to fall at this time of the year and the fact that it is not doing so shows that the turn has not yet come. The spring often leads to cheerful expectations of business, and firms are reluctant to let workers go if they anticipate an improvement. To some extent, therefore, there may be hidden unemployment which would reveal itself suddenly if it became clear that these expectations would not be realised.

Mr. Macleod announced special measures to relieve local unemployment—this time to facilitate the movement of workers from depressed areas to those where most industrial expansion was taking place. The measures included a grant of up to £50 to those moving house to find new work towards solicitors' and house agents' fees, and a rise in the grant towards moving expenses from £2 to £10. Industrial training and maintenance allowances will be raised by 10 per cent. If it is necessary to go beyond these and the other measures announced last month—designed to attract new industry to the depressed areas—the Chancellor of the Exchequer has given Mr. Macleod an assurance of financial support.

On the whole the Government are showing awareness of the dangers inherent in local unemployment. It has been a major problem since the end of the last century and must remain one wherever old industries die out in areas unsuitable for new ones. Artificial stimulus can be employed to attract industry and to move workers from depressed areas, but when the cause for unemployment is cyclical—as for example, in the ship-repairing industry at the present time—the finding of a solution is much more difficult.

Round Pegs Only

The Professional and Executive Register maintained and operated as a recruitment scheme by the Ministry of Labour and National Service has just celebrated its first anniversary. It claims, and probably rightly, a fair degree of success in bringing together employers and professional people in search of employment. One of its most useful functions has been to increase the mobility of professional workers.

Its claim to have succeeded in a number of instances in filling a vacancy where advertising had failed because the Register ensures that only qualified persons apply, brings two points to attention. First, it claims to have overcome what has been a source of criticism in the past in filling all kinds of vacancies through the Ministry of Labour—namely, that obviously unsuitable applicants turn up. Second, it emphasises the importance of setting out the requirements of a job correctly so that a large number of irrelevant applications are not sent in. There is always a temptation to judge the success of an advertisement for a vacancy by the number of replies. This appears to show that the advertisement was a good one because it attracted a wide interest and that the media for its insertion were also well selected. This attitude is likely to die hard, incorrect as it may be. Better a few good replies, as employee selection experts say, than a big but wasteful reaction. Any help the Register can continue to give in this direction will be a national service indeed in these days of a shortage of good engineers.

New Angle on Noise

The problem of noise in the factory is increasingly attracting the attention of scientific workers. The fact remains, however, that we have still to solve the problem of noise outside the works. Perhaps for scientific purposes they are the same problem. Be that as it may, outside the factory the control of noise is beset with considerable odds. A case has just been before the Court of Appeal concerning ice cream vending which sets this against a typical human background.

A fitter on night shift complained to the magistrates in a certain town that he was disturbed while trying to sleep during the day by an ice cream van playing a tune to attract sales. The defence was that the volume was not controllable, that competitor's followed the van and tried to cut out one tune with a louder musical noise and anyway that the composer had gone to great trouble to combine business with pleasure. The magistrates had turned down the complaint because only one "inhabitant" had complained, not several. Their lordships reversed the decision.

What starts with musical arrangements of doubtful taste may yet finish a long way from there. Other possibilities are factory hooters, two-stroke motor cycle engines and milk churns on railway station platforms close to houses or large hotels. There are powerful vested interests to be stirred before the problem of noise is fully dealt with outside the laboratory and the factory.

Tube Pay

The third major claim by transport workers, this time for increased wages and a 40-hour week for 18,000 London underground train workers, has been rejected. The London Transport Executive's reply explained that they had no funds from which they could pay increased wages. Like all the world's major train systems, London's tube is run at a loss and is subsidised by the bus service—and advertising.

The LTE's rejection was announced immediately before the unions were due to meet the Prime Minister last week to discuss a possible settlement to the railway wage dispute on the basis of operating economies and a quicker tempo of modernisation and re-equipment. Subsequently, speaking at the annual meeting of the Primrose League, Mr. Macmillan urged good sense over wages and made it quite clear that the Government attached considerable importance to the stabilising of prices. Only in this way, he said, was there any real hope of resuming industrial expansion. Once again he warned of the dangers, to the unions as well as to employers, of allowing Britain to become "an island of inflation in the world of deflation."

The unions will probably take the tube workers' claims to arbitration, though no decision has yet been made. Mr. Cousins returned at the week-end from his trip to Yugoslavia and will doubtless play a major part in influencing the course of the negotiations. The hopes that were aroused by the joint approach of the Transport Commission and the railway unions to the problem of freeing resources to better the pay and working conditions of employees through greater efficiency appear not to be less bright. Mr. Cousins will doubtless try to find a peaceful settlement since he must realise the Government's whole policy rests on avoiding either larger deficits or higher fares at the moment. How he will deal with the more militant tube train workers' demands for "joint industrialisation" on the part of the London tube and bus workers—which they are pressing hard—will probably reveal his intentions.

Crowns for Cooks

Army cooks, especially sergeant cooks, come within the same category as mothers-in-law. They are fair game for professional comedians when other ideas are scarce. In the minds of large numbers of soldiers and ex-soldiers of all ranks they are synonymous with half-cold, thin stew, prunes and custard, and hide-bound reactions to criticism—constructive or otherwise. Occasionally it has been conceded that under the sergeant's outward truculence there might beat the heart of a frustrated artist.

This may well be so. The latest figures of recruitment to the Army Catering Corps suggest that although there has been some improvement there is difficulty in recruiting because there are few chances of promotion from sergeant to warrant rank. As national service comes to an end the corps is faced with the need to establish messing as an Army trade on a similar basis to other Army trades as regards promotion. There is always the danger, however, that the more efficient the corps is in teaching the rudiments of the trade the more likely are army cooks to find civilian employment at the end of short-term engagements. The growth of industrial canteens is an increasing attraction in this respect.

Swords and Ploughshares

A training scheme for officers leaving the services as a result of cuts in the defence programme has been announced by Associated Electrical Industries. A two-year course is planned for between 110 and 180 officers who have no technical qualifications to give them the knowledge and experience required for employment in the electrical engineering industry.

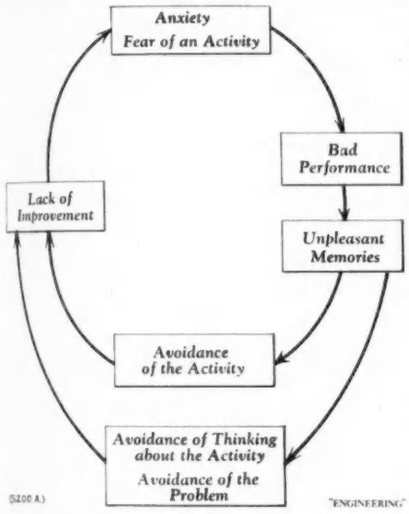
AEI, who have for many years been leaders in the field of industrial education and training, prepared the scheme in conjunction with the Officers' Association on behalf of the Regular Forces Settlement Service. They will endeavour to find jobs within the group for all who undergo the training though they obviously cannot guarantee to do so. The ex-officers will be paid at the minimum rate of £575 per annum during the first year and £650 during the second. Applications for training should be made to the Officers' Association, Windsor House, 46 Victoria Street, London, S.W.1, or to any local office of the Ministry of Labour and National Service—not to AEI direct.

ANXIETY AND ESCAPE

By Z. M. T. Tarkowski, B.SC.

The previous articles in this series described, in familiar engineering terms, some positive feed-back loops operating in human behaviour and linking an individual and the group. The preceding article discussed three types of instinctive reaction to danger which ordinarily maintain integrity and equilibrium in the organism, but are likely to lead to the establishment of spurious positive feed-back loops which may endanger stability. Now excessive anxiety is shown to have a disorganising effect on both the innate and acquired network of various zeroing mechanisms, and to be the main cause of the reversal of feed-back.*

We all suffer from anxiety from time to time and some of us more often than others. When anxious, a man is usually much less resourceful and efficient than he would otherwise be. His competence is impaired. The results of this are more tragic than is usually realised: in difficult situations or at a time of emergency when the keenest judgment and the exercise of one's highest mental powers are of most vital necessity, most people lose such clarity of thought and speech as they ordinarily possess; they become nervous, clumsy, even incoherent.



Manual dexterity is very often impaired at a time when its highest level is required. This applies equally to driving a car, piloting a plane or operating a machine.

Such maladjustment happens frequently in circumstances of real danger. Its effects are felt perhaps even more strongly in situations which, although important, are not really dangerous. Anxiety frequently spoils performance at examinations and tests, in courts of law, and in crucial interviews, when serious decisions are to be taken or difficult negotiations are in progress.

In these important and dangerous situations the presence of anxiety is clearly seen and appreciated, even if we do not know how to overcome it. But anxiety is, in fact, omnipresent. Consulting the boss, having to write a report or to address a committee, very often provoke considerable anxiety as well. It seems natural that we may be anxious when we are about to be reprimanded or when we receive a complaint. Many of us are no less anxious when we have to reprimand or criticise others or have to lodge a complaint. In such instances, the anxiety is somehow more painful and humiliating because it seems to indicate lack of courage. Thus, on such occasions, we are loath to acknowledge its existence.

* Previous articles in this series by Mr. Tarkowski have been:—"The Case of a Bad Mixer", 3 Jan. p. 11. "Criticism and Plain Speaking", 7 Feb. p. 177. "Stress and Strain in Human Relations", 7 March, p. 305. "Three Human Reactions: Aggression, Submission or Escape", 4 April, p. 429.

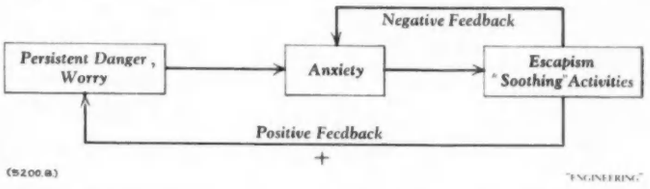
Anxiety is extremely unpleasant to experience and may be even physically painful. In addition, some of our traditions lead us to think that its presence is contemptible and humiliating. As a result, many people pretend to others and to themselves, and indeed manage to deceive themselves, that they are not subject to anxiety. In consequence, it is covered up, suppressed or even repressed so that it becomes unconscious.

Among other things which may precipitate anxiety are such events as new or unfamiliar tasks and assignments, a new job, a new boss or a new colleague. Having to meet a stranger or to participate in a social occasion are among the best known and acknowledged causes of apprehension. When reorganisation or other changes are in progress, and even when they are only proposed, people are likely to become inordinately anxious.

Even minor anxiety—for instance, when contributing to a discussion at a meeting—is often accompanied by various physical symptoms: shivering, hot and cold sweats, increased heart-beat, dry mouth or choking sensations in the throat, feelings of pressure or tension in the head or chest, nausea, trembling, feelings of restlessness or paralysis.

There are several ways in which the painfulness of experiencing and acknowledging anxiety is avoided. Its existence may be denied and when the self-deceit is fully successful, it becomes completely repressed. In such instances only physical symptoms remain and it is through them that the presence of unconscious anxiety can be recognised.

Among other ways of escaping the painful experience of anxiety, the two most important are the avoidance of the anxiety-provoking situation and engaging in all manner of distracting or "soothing" activities, whose recognised or unrecognised purpose is "taking the mind off" the worry. Thus, the actual cause of the worry is, at best, never tackled, and sometimes actually made worse. This gives rise to some more vicious circles which we will consider later.



Many people put off opening envelopes when they are expecting bad news. There are those who find making their family budget, adding up their bills or their cheque counterfoils too unpleasant to face up to. Important tasks about which one feels apprehensive or inadequate are very often postponed; they loom larger and larger and begin to appear much more formidable than they actually are. Thus, negligence and worry reinforce each other and form a vicious circle. One avoids thinking about a difficult problem and the longer it is avoided, the more difficult it usually appears. One avoids speaking in public or expressing criticism if this arouses apprehension and the longer the avoidance, the more incapable one becomes of engaging in the activity of which one is frightened.

There are many forms of distracting and "soothing" activities: superficial conversation, superfluous visits and telephone calls, unnecessary gossiping. All these are wasteful of time and may be intensely annoying to others. Compulsive buying, eating and smoking also belong here and so does inordinate need for sleep. For some people, seeking out scapegoats and witch-hunting provides a distraction from their own worries. Needless to say, excessive drinking and addiction to drugs are extreme examples of the same phenomenon.

THEORETICAL DISCUSSION

A living organism exhibits many examples of what has been called *homeostasis* by W. B. Cannon.[1] These include the maintenance of constant temperature, blood-sugar level, blood oxygen content and many others. Homeostatic phenomena, one instance of which is the thermostatic control of the body, are bound, it would seem, to be subserved by what the engineer calls zeroing mechanisms and these are composed of one or more feed-back loops.

In many cases, for instance, in connection with the maintenance of the blood-oxygen level, the actual feed-back paths have been experimentally found, though the complete mechanism is likely to be much more complex than is our present knowledge of it. Transmission of information within the body is, very broadly, of two types. One type of pathway is provided by electric impulses along nervous fibres. The second type of transmission is through hormones and other chemical substances transported by the blood stream and permeating selectively the tissues through semi-permeable membranes.

For example, as was mentioned in a previous article,[2] the information of impending danger is carried by adrenalin and nor-adrenalin in the blood stream, being conveyed eventually to the appropriate muscles. The signals triggering off actual physical action travel along nervous pathways, and when the action takes place the hormonal substances are used up.

It has been pointed out by some writers, most notably by E. S. Russell,[3] that the homeostatic processes occur not only within the body, but also within the larger system, entailing both the organism and its environment. To use Russell's example, the thermostatic control of the body takes place not only through internal mechanisms controlling the rate of combustion and heat production within the cells of the organism, but also through such mechanisms affecting the environment, as, for instance, building nests. Thus, when the reduced air temperature causes loss of heat in the body, this leads, in turn, to a pattern of muscular activity resulting in construction of a nest which, in turn, prevents further loss of heat and brings the body temperature back to normal. This has been shown experimentally.

Similarly, when anything happens, outside or inside the body, which causes pain, some action is triggered off in the organism leading through internal or external feed-back paths to the removal of pain. The healing of wounds belongs to this category, and so does the repair of damage through behaviour utilising some features of the environment. Detailed examples of this are given by Russell.[3] There are also experimentally known cases of animals which, when suffering from a deficiency of a certain chemical compound, acquire a taste for and seek out various substances in their environment which, through a chain of chemical processes, eliminate the deficiency, after which the transistory taste vanishes. Frequently, these "replacement" substances are not normally eaten by the animals concerned, and their flavour and appearance may have no connection at all with the particular compound which will be finally manufactured from them.

The three reactions to danger discussed in the previous article[4] are examples of such homeostatic mechanisms, where the feed-back loops involve both the organism and its environment. When the action is successful and the danger disposed of, the organism returns to quiescence. There are, however, many instances when, perhaps through some loss of calibration, the working of these mechanisms becomes erratic, and their zeroing function is not achieved;

Research and Development

TWO-TERMINAL CONSTANT CURRENT DEVICE

A two-terminal, passive semiconductor component having novel and useful characteristics was described at the recent annual convention of the Institute of Radio Engineers in New York. The experimental device, known as a field effect varistor, was developed by R. M. Warner, Jr., H. A. Stone and E. I. Doucette of Bell Telephone Laboratories.

This component has a constant-current feature which makes it suitable for use as a current regulator in circuits where either the load or supply voltage vary over wide limits. It can also be used as a current limiter or pulse shaper. Its a.c. impedance is very high, making it useful as a coupling choke or an a.c. switch.

The device, closely related in principle to the field effect transistor, contains a single planar junction which is made by diffusion. Current passes parallel to this junction through a constricted region called the channel. As the voltage across the device is increased, current increases and a depletion layer builds up until it eventually reaches through the entire thickness of the channel. At this point, called the " pinch-off " point, a further increase in voltage does not produce any increase in current. Eventually an avalanche breakdown occurs, as the voltage is increased still further. Between the pinch-off and breakdown points, the current is essentially constant, and this is the region of maximum interest.

At present the varistors are fabricated by cutting dice from a slice of germanium or silicon containing a single diffused junction. The dice are heavily plated on all surfaces, and a circular trench is then cut into the diffused layer to within about 0·1 mil of the junction. This cutting requires a high degree of precision, since the characteristics of the final device depend heavily on the spacing between the bottom of the trench and the junction. In exploratory work, the trench is first cut with an ultrasonic tool, and finished to the desired depth by etching. Leads are then attached by thermo-compression bonding or other convenient means.

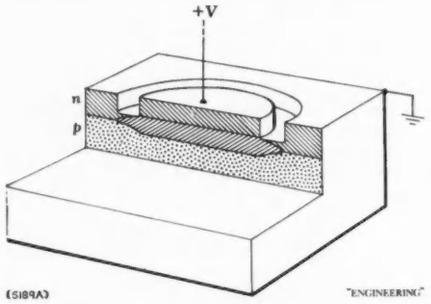


Fig. 1 Varistors are fabricated, at present, from crystals of germanium or silicon containing a single diffused junction. The spacing between the trench and the junction is critical.

Characteristics of the device can be altered by varying such parameters as channel depth, impurity gradient, length and width of channel, and selection of semiconductor material. Using silicon, units have been fabricated with a regulated current of 1 mA, pinch-off voltage of 10 V and breakdown of 150 V. Current can be held constant to within 1 per cent over a voltage range of 20 to 120 V.

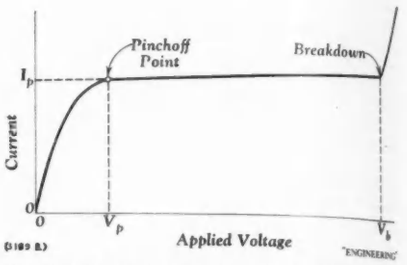


Fig. 2 The Varistor has useful constant-current characteristics.

Germanium units with a rating of 10 mA, pinch-off of 10 V, and breakdown of 25 V have been made. It appears feasible at present to produce varistors which regulate current at any level between 10 μA and 10 mA, and improvements in fabrication techniques should make higher current levels feasible.

For circuit applications, a parasitic shunt capacitance of the order of a few picofarads, is present, which must be taken into consideration. In the constant current region, the ratio of a.c. impedance to d.c. resistance is typically 100 and may run as high as 1,000, making it ideal as a coupling device. It differs from the conventional choke in that its a.c. impedance is constant over an appreciable frequency range.

Continuing Anxiety and Escape

furthermore, there are cases when, through some fault, instead of negative feed-back, a spurious positive feed-back loop comes into operation.

There are various circumstances, which we will discuss more fully at a later stage, when the instinctive reactions to danger become blocked or distorted through internal conflict or loss of synchronisation. This causes anxiety, or increases it, and anxiety, when it reaches a certain level of intensity, starts having disorganising effects too. An action appropriate to the removal of danger becomes less and less possible, while the anxiety becomes more and more acute and painful. When this happens, another homeostatic circuit, i.e., negative feed-back loop, comes into operation. This may lead to an immediate and temporary diminution of anxiety, but it does not remove, and may even aggravate, the external danger.

An excellent example of this process in human life is when some external hardship, say financial worry, causes anxiety which may be temporarily relieved by alcohol; this removes the pain, which may be intolerable, but instead of solving the financial problems it aggravates them further.

This vicious circle can be overcome by a very thorough examination of the situation. Such examination, however, itself causes anxiety, and is therefore very painful and difficult.

There is an interesting and authentic example which illustrates this point very well. A sales manager was getting periodically depressed about the unsatisfactory volume of business. His natural temptation was to call a sales conference, at which he would speak at length about the necessity for greater efforts. That would make him feel better, but at the end of the next accounting period the number of transactions was smaller, due to the fact that the salesmen had been taken off the road.

APPENDIX

The ways of escaping anxiety, its repression, physical manifestations, and disorganising effect on work and human relations, are very fully discussed by Karen Horney in her illuminating books[5, 6] and more especially in *The Neurotic Personality of Our Time*. In 1937 she proposed the theory that *basic anxiety*, originating in childhood, and perpetuated usually throughout life, is the main causative factor in most forms of non-adaptive or self-defeating behaviour.[5] She has also stressed the influence of *cultural tradition* in causing *anxiety* and *conflict* (*ibidem*).

The term *homeostasis* has been introduced by Cannon and references to original experimental work on the control mechanisms of the body will be found in his book.[1] The idea of the existence of some form of zeroing mechanisms in the living organism was introduced for the first time by Claude Bernard in 1855, who referred to it as the maintenance of the constancy of the *internal environment* (*milieu interne*). Many examples of homeostasis will be found in Morgan and Stellar.[8]

Bernard's *internal environment* refers to the composition of the fluids of the body. This was called by Cannon the *fluid-matrix*, and *homeostasis* can be defined as the automatic maintenance of the uniformity of the fluid-matrix in spite of changes in the external environment. Extensive discussion of the regulating mechanisms will be found in Fulton's text-book[9, 10, 11] These involve various divisions of the autonomic nervous system, the cerebral regulation of autonomic function, and the endocrine system. The phrase, *the wisdom of the body*, was apparently suggested in 1923 by Starling.[11] An elementary introduction will be found in Winton and Bayliss.[12]

The fact that homeostatis is subserved by several alternate routes, some of them involving the external environment and motor behaviour of the whole organism, emerges from the extensive experimental work of Richter, to whose publications references will be found in E. S. Russell.[8]

Of particular interest to engineers will be Ross Ashby's discussion[14] of regulation and control in biological systems, including various features of negative and positive feed-backs. The idea that regulation can be achieved via behaviour and the external environment is considered by him, from the cybernetic point of view, in his *Design for a Brain*.[15]

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TORSIONAL WAVE DELAY LINES

Delay lines are useful in many applications such as computer memories, trigger delay circuits, range-measurement circuits in radar installations, and in pulse decoding systems for electronic switching. The packaging of these delay lines in a small volume is important.

A delay line capable of providing a long delay in a small space was described at the recent Institute of Radio Engineers annual convention, in a paper prepared by R. N. Thurston and L. M. Tornillo of Bell Telephone Laboratories. Known as a spiral coiled wire torsional wave delay line, it permits the clear resolution of 10 microsecond pulses spaced 20 microseconds apart.

The delay line consists essentially of a length of 0·038 in diameter wire made of Vibralloy which has been coiled into a spiral to conserve space. Vibralloy, a ferromagnetic alloy developed at Bell Laboratories, is used as it has a high mechanical Q (low losses) and low temperature coefficient of delay.

Torsional strain waves travel through the wire at about $2{\cdot}68 \times 10^5$ cm/sec, making the theoretical delay about 3·72 microseconds per cm. In one experimental line, a 15 ft length of wire exhibited a delay of 1·65 milliseconds at 840 kc/s. The wire was coiled into a spiral of about 4 in diameter and then heat treated at 500° C for $1\frac{1}{2}$ hours.

Ceramic torsional transducers are used to inject and detect the torsional waves. The transducers limit the bandwidth of the system to about 11·5 per cent. Total insertion loss for the 1·65 millisecond line was 9 dB, of which 6 dB was line loss and 3 dB represented conversion loss in the transducers. Bandwidth was about 100 kc/s.

A number of experimental delay lines have been built using this technique. Results indicate that such delay lines are small in size, rugged, reliable, and relatively insensitive to moderate changes in temperature.

FARM ORGANISATION*

By Rex Paterson

Influence of Machinery Developments

The development of agricultural machinery of all kinds has been very rapid during the past 20 years. Among all the good things offered, the farmer must make his choice, and it is not an easy one. Each machine may have individual merit, but they all require a capital investment, which may easily lead to further capital needs to make good use of the first purchase. Thus, where the acreage is small, serious difficulties of over-capitalisation easily arise, and from time to time considerable readjustments of aims and objectives become necessary.

GENERAL LAYOUT OF FARMS

The present time is one of these occasions when we must think with special care about our future because we are offered help and encouragement by the Government to reconstruct our buildings. Buildings are now regarded by many farmers as on a par with machinery, except that they are less easily scrapped and replaced when a better design becomes available.

Our farms vary in size. There is no kind of uniformity such as is sometimes found in other countries, where the size is often controlled by what one man can do according to the type of farming in his area. The layout of farms in many countries has been a recent development, and has often been varied rapidly to suit changing needs. The British pattern, on the other hand, has been set in the past, and often has buildings of heavy stone which are not always conveniently located in relation to the land they serve. Some areas are traditionally devoted, almost exclusively, to livestock, whereas others are devoted to grain growing, seed production, sugar beet and potatoes, often without any livestock. Some farms are on flat well-drained land, while others are on hilly, or badly drained areas, ill suited to cultivation.

Flat, easily cultivated areas can use all types of machinery to the fullest advantage, and can probably grow most crops as cheaply as anywhere in the world. Such areas are frequently in districts of lower rainfall, so that there is less interference in field work from the climate. The large size of many of these farms enables them to use machinery economically. Crop residues will either be desiccated with suitable machines and thrown back on the soil to maintain the humus, or harvested with pick-up balers in the case of straw and hay for sale, or the use of livestock. The pattern is clear cut and fairly simple. The most difficult problems of machinery usage arise in the wetter areas, where acreages are small and slopes are bad. In such areas transport about the farm, and often on public roads, which may be narrow, is a difficulty, and the remarks in this paper will be devoted particularly to these areas.

They are mainly found in the western half of the British Isles, and are predominantly devoted to mixed farming with the emphasis on livestock. Such farms are usually small, and managed by the farmer and his family. Their problems are less concerned with the crops of the eastern half of the country than with the difficulties of balancing the winter feed requirements of their stock with the feed they can grow in summer. The majority of them now have tractors, and horses are, in many cases, a thing of the past. Although a certain amount of corn is still grown they obviously cannot compete with the large grain growers, but straw is required, and the cost of buying it in would be excessive. To continue grain growing with all the expense of ploughing and cultivating, which means having a full line of equipment for a small acreage, looks uneconomic. So long as prices remained high in relation to costs these things could continue but the margin is being reduced, and it may be difficult to continue. What are the alternatives?

MAKING SILAGE OR HAYMAKING

Much advice has been given regarding the advantages of making silage instead of hay, yet pick-up balers are being bought in large numbers and haymaking continues, although there is a considerable increase in silage making. Is this because haymaking is traditional, or because haymaking with the pick-up baler fits the organisation and layout of the farms? It must be recognised that feeding small numbers of different kinds of stock is more easily done with hay than with silage. It is also inconvenient and more difficult to make small quantities of silage.

This is the crux of the whole problem of the use of new machines. Some of them offer possibilities of reorganising farming, but the changes required may be too drastic to achieve universal acceptance. The result is that farmers continue to follow traditional methods because, on the whole, it fits their system. If a farmer has old pastures which do not produce a crop worth cutting before late June, when it is unfit for silage making but probably easily dried, if he is lucky with the weather, he will naturally make hay. He may also have been busy on some root growing which kept him from silage making in May and early June.

However, if a man has eliminated root growing and replaced some of his old pasture with young leys, which he has manured liberally, he will have such an abundant luscious growth by late May that he will have difficulty in making hay. On the other hand, he will have excellent material for silage making, and little choice but to make it into silage. However, the farmer must be convinced that a change to liberal manuring is both economically desirable and financially possible before he will make this change. There is increasing evidence that such a policy leads to higher production and lower costs than the traditional system of hay and cake feeding.

Once he has made a decision to change his system of livestock keeping he becomes interested in how to spread his fertiliser with the most suitable machinery and how to harvest and store his surplus growth as silage. If he keeps milking cows he may have to increase his herd to use all the feed he can grow and will therefore be interested in easier ways of handling his cows so that he can milk a greater number without increasing his labour requirements. With this new train of thought in his mind many new problems will present themselves. If he is going to redesign his milking shed, is it located in the best place? Must he keep his cattle indoors in winter if he wants to use less bedding, or can he find some dry winter ground which is reasonably well sheltered for his cattle to lie outside all winter? If he makes silage, will he self feed it, or must he move it to the cattle? If he can only cut certain fields should he locate his silage storage point near this area, and what effect will this have on the equipment he uses for harvesting this silage?

REPLANNING

All these considerations may require a replanning of his farm; possibly some new roads, perhaps the opportunity to use an existing road to better advantage, or the possibility of avoiding the crossing of a main road. He may well find that a centre for handling, feeding or milking cattle does not need to be adjacent to the existing homestead. In fact much lost time in transport and risk of lameness through walking livestock too far may be avoided by such changes. If his herds are large should there be more than one centre? If so, what is an economical number of cattle to handle in one herd? Should it be what one man can handle, or is it preferable that two men should be together?

Our own experience is leading us towards herds of 60 or so cows, milked and fed by one man. Experience suggests that a man can look after about four sets of cups in a tandem bail, that is he should milk 40 cows an hour; or up to six or eight sets in a herringbone type bail where he should milk 60 or more cows per hour. To our surprise we are finding that good men prefer to run these herds alone, but every detail of the layout and the approaches must be right to achieve easy handling. We have found it advantageous to take the shed out to a fixed site, away from the main buildings, but easily reached from all fields. We have found this to be true on small as well as large farms unless the original buildings were well sited. Similarly, to achieve a high output per unit of labour if silage is fed it is often better if self-fed at a point accessible to the herd in wintertime.

Harvesting grass for silage can now be done with a variety of different machines, all of which reduce, or almost entirely eliminate, the use of hand labour. But here again the method should fit the labour and power available on the farm. The dairy herd, or unit of other stock, to be wintered may be the whole enterprise of the farm. If this is equivalent to 30 head of cow equivalents the whole of the farm work, including the harvesting of the winter feed, should, if possible, be done by the same unit of labour as looks after the cattle, if that labour is to be as productive as on a larger farming unit. On a 60 cow unit an extra man could be carried. This standard of achievement may be a little high, but the real purpose of organisation and mechanisation is two-fold—to make work easier and more pleasant, and to overcome peak labour requirements so that too much partly employed labour is not carried throughout the year to cope with peak labour loads.

FORAGE HARVESTERS

This must be our criterion in judging the suitability of new machines. At first sight some of these new forage harvesters have a wonderful output. They can cut and load sufficient grass to keep, perhaps, three trailers at work transporting the grass to the silo. Unfortunately young chopped grass packs too tightly to make good silage, and if the normal method of allowing it to heat up before adding more is followed, the crew cannot be kept at work without several silos to fill at once: yet a certain amount should be added daily. To get over this on large farms the outfit may move from one area to another to fill different silos. There is also difficulty in driving on to the silo because of over-consolidation of the surface, and either a buckrake is used to carry the grass on, or it is fed into an elevator by hand. Is this good organisation which is adaptable for many farms? Probably not, but it is not necessarily the fault of the machine.

The answer here seems to be to start using forage harvesters of this type capable of cutting short grass early in the season and to work steadily through the season, but only with a small gang, or for a short day. This may be inefficient use of the capacity of the machine, but it is perhaps making the machine the servant and not the master. Here again one may meet other problems such as the length of growing season when there is a true surplus of grass available for cutting. In some areas grass grows steadily and is dense in the bottom, but all too often it seems that one can barely find enough grazing for the stock until there is either a good rain, or warmer weather in late May, when, all of a sudden, there is a surplus everywhere, requiring immediate cutting. In these circumstances a buckrake bringing in long grass, which traps sufficient air to provide adequate heating, may be the most economical way of storing the crop, and the capital cost will be low. For the benefit of anyone not familiar with silage making it may be necessary to explain that for the conservation process some air should be trapped in the grass as it is stored to create a desirable type of fermentation. If all air is driven out by using short wet grass an anaerobic type of fermentation may develop which is undesirable.

The point to be emphasised is that a large farm with a staff to be moved from one harvesting operation to another as the season progresses may have the strength of labour and power to harvest silage in a short period. A smaller farm, on the other hand, without other crops and employing, at the most, two people may require quite different organisation and equipment. Two cases come to mind. One farm milking 60 to 70 cows with one man who makes all the silage necessary with the help of a tractor driver. They use a mower and two buckrakes. All the grass is cut in a relatively short period of three to four weeks, but they work early and late to do it On a second farm, where 100 cows are milked, two men and the boss cut grass throughout the season with a forage harvester, but work no overtime. It would be hard to say which was the better organisation.

OUTSIDE LABOUR

Some people might suggest that the more expensive type of equipment could be used by contractors, who went from farm to farm. It is doubtful if this could be done to advantage because of the difficulty of filling a small silo rapidly. The crop will not go in until it settles down, which takes at least five days; preferably, filling should extend over a much longer period. Therefore, the best that can be done is probably for two or three neighbours to work together, care being taken to avoid a big gang, because output soon falls if any critical part fails and, as mentioned before, fast filling rates in only one silo are seldom practicable, unless it is a very big silo.

America is the home of tower silos, which are often filled rapidly by a contractor moving from farm to farm. If they can do it, why cannot we? Their crop is usually maize, which makes good silage, however fast it is stored. Maize is also a crop which should be fairly mature before it is cut—a very different matter from harvesting young grass which

* Paper read before Section G of the British Association at Dublin on Tuesday, 10 September, 1957.

Continuing

Research and Development

is changing its composition daily. In America they have similar, or even greater, problems than we when putting young grass in silos. Their grass grows even more rapidly than ours so that it is only at the right stage for cutting over a very limited period. There is also more clover or lucerne in their cuts. They have tried to overcome the difficulty of sour silage by using various additives, the most recent one being sodium metabisulphite. However, reading through their reports, one constantly finds conflicting evidence of its benefits accompanied by the remark that if they can wilt so as to store with no more than 65 to 75 per cent. moisture good silage will generally be obtained. They also report that higher outputs are obtained if cutting is done as a separate operation when making grass silage.

We are thus back to our original problem. We can eliminate or reduce haymaking on the stock farms, but if we do so, how are we to equip ourselves? If the smaller farmer wishes to be competitive with his larger neighbour he must keep his investment in machinery and buildings at as low a level as possible. If he is a milk producer he should surely aim at equipping himself so that he can keep at least 30 head of cow equivalents per man employed, and to do it on not more than 75 acres, preferably on 60 acres. He may also keep some pigs and poultry so that sometimes there may be two labour units available. We can, perhaps, assume that the forage harvesting should be done by two people on the majority of farms. Should it be long grass brought in with the buckrake, the green crop loader or baled?; or should it be cut bruised and loaded on a trailer with one of the new type forage harvesters? This might mean that two or three neighbours should work together.

CONCLUDING CONSIDERATIONS

Green forage harvesting as silage is bound to increase in popularity as a means of pasture control and provision of winter feed. It will eliminate some of the worries and waste of haymaking. However, it means such a change of methods, such as a greater use of fertiliser, and such changes in layout of buildings to make them more easily accessible for storing and feeding silage, and handling the cattle, that we cannot expect these things to come about in too brief a period. Most farms in livestock areas are geared to haymaking and feeding, and will remain so until the farmers are convinced that a change is desirable. In the meantime farmers, research workers, time and motion study experts and engineers must closely watch developments of forage harvesting in small farm areas to decide the answers to the following questions:

(1) On livestock and particularly dairy farms, what type of pastures will be grown, and how will they be fertilised?

(2) Will the aim, or the result, be that grass grows steadily throughout a long period, so that the surplus can be harvested over a long period. Or will the surplus tend to occur in a brief period from mid-May to mid-June?

(3) Do we want to cut and bruise our grass, or are we satisfied that if we follow proper techniques we can make good silage from long grass? Which do the cattle prefer, and are there any variations in the recovery and palatability of the stubble behind different methods of cutting?

(4) How much have we still to learn about storing grass for silage? Does chopping make it easier to store, or does it add complications? Shall we end by using additives or dry straw, hay, or by wilting?

(5) Shall we store for self feeding at about a 6 ft. depth, or in narrower and deeper silos which will require less roofing per ton stored? Does silage require covering, anyway?

(6) To economise on labour shall we reduce the length of haul by storing near where the crop was grown, or shall we only grow the crop near where it is to be stored, or shall we disregard the length of haul? All these considerations will influence the development of forage harvesters, and so will any parallel developments in haymaking methods.

Perhaps what we are looking for is a highly manoeuvrable self-propelled forage harvester which will front cut, load and carry its own load to the silo. If it had a good road speed it could quickly travel between farms if it were a contractor's tool, so as to put only a moderate amount of grass in each silo per day. It should be able to travel over the silage and require only one man to operate. The farmer could do the spreading. No doubt farmers would be content if such a tool were directly pulled by a tractor, because if it lost something in manoeuvrability it would gain in being priced within the range of more users. Such tools as this are being made.

PITCH AND ROLL MEASUREMENTS ON A DOUBLE-DECK BUS

Data Needed for Designing the Gyreacta Transmission

The riding quality of a road vehicle is a function of the accelerations and velocities, both linear and angular, to which the body of the vehicle is subjected when in motion. Linear motions are generally recorded by means of accelerometers, and information on such movements is available, but little appears to be known about the angular movements of typical road vehicles.

The importance of this subject was recently emphasised in connection with a new type of vehicle transmission. Gyreacta Transmissions Limited, a subsidiary of the National Research Development Corporation, have sponsored a limited investigation of the problem in connection with the Clerk Gyreacta. This system incorporates a flywheel running at high speed and acting as an energy store. When slowing down the kinetic energy of the vehicle is transferred to the flywheel, to be subsequently withdrawn when the vehicle is set in motion. In this manner the demands on the engine are reduced and, in vehicles which start and stop frequently, a substantial fuel saving is to be expected.

The Gyreacta flywheel runs on a vertical axis; it is thus insensitive to cornering, but angular

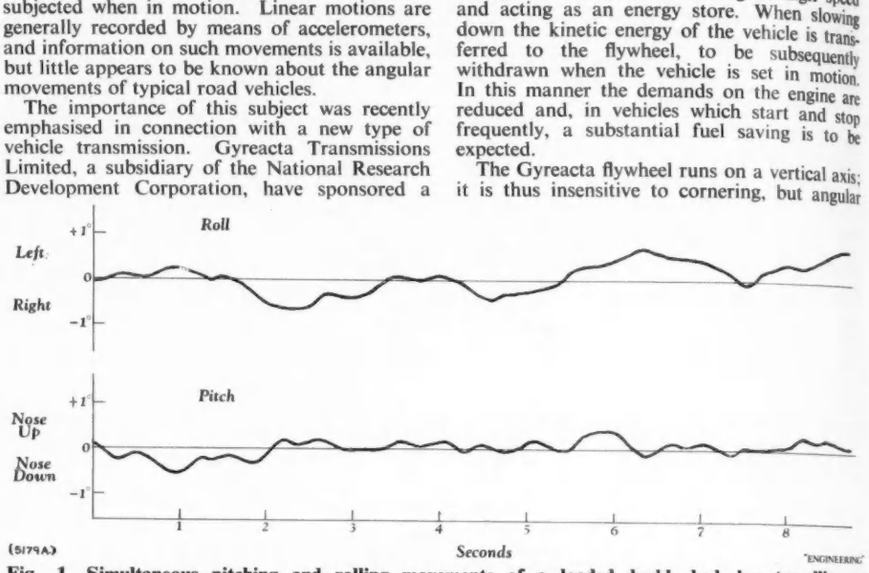


Fig. 1 Simultaneous pitching and rolling movements of a loaded double-deck bus travelling at 25 m.p.h. on a typical suburban road.

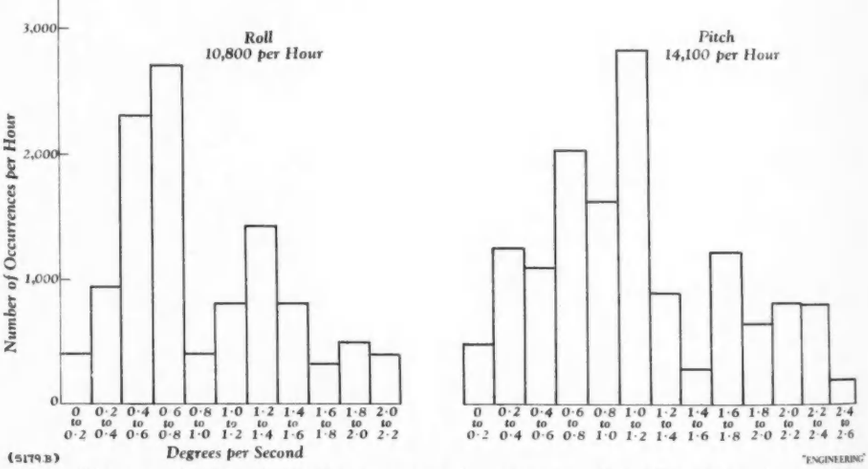


Fig. 2 Histogram showing relationship between maximum angular velocities in pitch and roll and frequency of occurrence of these velocities. The road conditions were similar to those represented in Fig. 1.

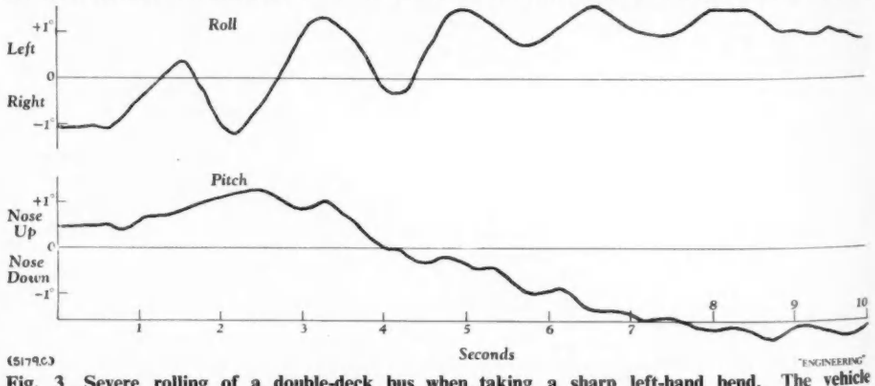


Fig. 3 Severe rolling of a double-deck bus when taking a sharp left-hand bend. The vehicle experiences angular velocities in roll of up to 4·5° per second.

movements about the longitudinal (roll) and transverse (pitch) axes of the vehicle give rise to substantial precessional couples. These are proportional to the product of the angular momentum of the flywheel and the angular velocity of pitch and roll. In order to design the flywheel bearings and suspension it was necessary to know the nature of the angular disturbances to which it would be subjected in service, and Plint and Partners Limited, Wargrave, Berkshire, the company responsible to Gyreacta Transmissions for the development of the transmission, have produced an instrument for obtaining this information.

This instrument works on the same principle as the recorders used for studying the pitching and rolling of ships, but is specially designed to deal with the much smaller amplitudes and higher frequencies experienced by road vehicles. The sensing element consists of a gyroscope, mounted at its centre of gravity and with its axis vertical. The relative position of the vertical axis of the vehicle and the gyroscope axis is recorded by an electronic method which eliminates all friction, and curves of pitch and roll attitude are produced directly.

Tests were taken on a fully laden Type D7 double-deck bus built by the Birmingham and Midland Motor Omnibus Company Limited, the type of vehicle in which the prototype Gyreacta transmission is to be installed, and typical records are reproduced herewith. It was found that the vehicle was subject to two distinct types of disturbance: Fig. 1 is part of a record which is typical of the behaviour of the bus when travelling on a substantially straight road of moderate surface quality. The two curves show respectively the roll and pitch attitudes of the vehicle at successive instants. Rolling is irregular in nature, with a total range of 1·4°; an analysis of this and other tests shows that the average frequency of roll, for small disturbances, is 1·4 cycles per second. Pitching is more regular with a range of 1° and an average frequency of 2·1 cycles per second.

In connection with the Gyreacta flywheel, most interest attaches to the maximum angular velocities attained and their frequency of occurrence; a similar criterion may be expected to apply with regard to the comfort of passengers. Fig. 2 is based on Fig. 1 and shows the distribution diagram connecting maximum angular velocities and frequency of occurrence, a maximum occurring at each point of inflection in the curves of Fig. 1. Pitch maxima are both more frequent and of greater magnitude than roll maxima, reaching values of up to 2·6° per second.

The second type of disturbance occurs when cornering, and Fig. 3 shows a typical record obtained while driving fairly smartly round a sharp left-hand corner. The vehicle develops a pronounced roll having a period of 1·5 to 2·0 seconds and a range up to 2·5°, the maximum angular velocity reaching 4·5° per second. The change in mean pitch and roll attitude during this recording is due to a change in road slope, from uphill before the corner to level after it.

Further tests at the Motor Industry Research Association Proving Ground, in the course of which the vehicle was driven at high speed in a zigzag path, showed that it was possible to build up rolling oscillations of up to ± 2·5° amplitude, the period being about 3·5 seconds and maximum angular velocity 5° per second; it is unlikely that, except under accident conditions, the angular velocity would ever exceed this figure.

A fully developed version of the pitch and roll recorder used in these tests is shortly to be placed on the market.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LEEDS
"Silicones," with films, by R. Nattras. Leeds Branch. Great Northern Hotel, Leeds. Mon., 5 May, 7.30 p.m.
MANCHESTER
"Earth Leakage Protection of Electrical Installations," by J. A. Robbins. Manchester Branch. Engineers' Club, Albert Square, Manchester. Wed., 7 May, 7 p.m.

Chemical Society

LONDON
Heinrich Wieland Memorial Lecture by Professor Dr. R. Huisgen. Thurs., 8 May, 7.30 p.m.
EXETER
"Stability of Metal Complexes," by Dr. H. M. N. H. Irving. Washington Singer Laboratories, Princes of Wales Road, Exeter. Fri., 9 May, 5 p.m.

Combustion Engineering Association

LONDON
"The High Duty Combustion Chamber," by R. P. Fraser, at 10.30 a.m. "Coke in Industry," by E. Murphy and A. S. Boyle, at 2.30 p.m. Southern Region. St. Ermin's Hotel, Caxton Street, Victoria, S.W.1. Tues., 13 May.
CARDIFF
"Back Pressure Generation," by P. F. Morgan, at 10.30 a.m. "Planned Maintenance," by T. W. Fishlock, at 2.30 p.m. Park Hotel and Whitehall Rooms, Cardiff. Wed., 7 May.

Helicopter Association of Great Britain

LONDON
"Canadian Research in the Field of Helicopter Icing," by J. R. Stallabras. Royal Aeronautical Society, 4 Hamilton Place, W.1. Fri., 9 May, 6 p.m.

Illuminating Engineering Society

SWANSEA
Informal Meeting. Swansea Group. Offices of the South Wales Electricity Board, The Kingsway, Swansea. Mon., 5 May, 6.30 p.m.

Incorporated Plant Engineers

LONDON
"What Management Requires of a Plant Engineer," by W. J. Worsdell. Royal Society of Arts, John Adam Street, Adelphi, W.C.2. Tues., 6 May, 7 p.m.*
CHESTER
"Heat Exchangers," by A. Faunbern. Mersey and North Wales Branch. The Blossoms, Chester. Mon., 12 May, 7.15 p.m.
GLASGOW
"Oil Firing as Applied to Steam Raising Plant," by A. W. Rooney. Glasgow Branch. Scottish Building Centre, 425-427 Sauchiehall Street, Glasgow. Thurs., 8 May, 7.15 p.m.
MANCHESTER
"Selection of Machine Tools for Maintenance Departments," by R. G. Clowes. Manchester Branch. Engineers' Club, Albert Square, Manchester. Tues., 13 May, 7.15 p.m.
PETERBOROUGH
"Engineering Problems in the Beet Sugar Industry," by Dipl. Ing. K. Hample. Peterborough Branch. White Lion Hotel, Church Street, Peterborough. Tues., 6 May, 7.30 p.m.
SOUTHAMPTON
"Generation of Power from Atomic Energy," by H. R. M. Hyder. Southern Branch. Polygon Hotel, Southampton. Wed., 7 May, 7.30 p.m.

Institute of Fuel

LONDON
"Improved Sampling Equipment for Solids in Flue Gases," by P. G. W. Hawksley, S. Badzioch and J. H. Blackett. Institution of Civil Engineers, Great George Street, S.W.1. Wed., 7 May, 5.30 p.m.*

Institute of Petroleum

LONDON
"Recent Developments in Refining," by W. J. Newby. Wed., 7 May, 5.30 p.m.*

Institute of Road Transport Engineers

CARDIFF
Discussion on "Welding Techniques in the Construction of Modern Goods and Public-Service Vehicles." South Wales Centre. South Wales Institute of Engineers, Park Place, Cardiff. Fri., 9 May, 7 p.m.

Institution of Civil Engineers

LONDON
"Design and Performance of the Sasumua Dam," by Professor K. Terzaghi. Tues., 6 May, 5.30 p.m.*
"Volta Bridge," by P. A. Scott and Gilbert Roberts. Tues., 13 May, 5.30 p.m.*

Institution of Electrical Engineers

LONDON
"Some Case Histories of Business Computers in the U.S.A.," by Dr. A. T. Starr. Measurement and Control Section. Tues., 6 May, 5.30 p.m.*
"Artificial Fibres," by Dr. P. T. Standring. Utilization Section. Thurs., 8 May, 5.30 p.m.*
Discussion on "The Teaching of Applied Acoustics," opened by G. Mather. Education Discussion Circle. Fri., 9 May, 5.30 p.m.*
Annual General Meeting and Film Display. London Graduate and Student Section. Mon., 12 May, 6.30 p.m.*
BELFAST
Annual General Meeting. Northern Ireland Centre. Civil Engineering Department, David Keir Building, Queen's University, Belfast. Tues., 6 May, 6.30 p.m.
BIRMINGHAM
"Electric Control of Stage and Television Lighting," by F. P. Bentham. South Midland Centre. James Watt Memorial Institute, Great Charles Street, Birmingham. Mon., 5 May, 6 p.m.*
GLASGOW
Annual General Meeting. South West Scotland Subcentre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. Wed., 7 May, 7 p.m.
LEEDS
Annual General Meeting. North Midland Centre. Offices of the Yorkshire Electricity Board, 1 Whitehall Road, Leeds. Tues., 6 May, 6.30 p.m.
MANCHESTER
Annual General Meeting. "Supply-Voltage and Current Variations Produced by a 60 ton 3 Phase Electric-Arc Furnace," by Dr. B. C. Robinson and A. I. Winder. North Western Centre. Engineers' Club, Albert Square, Manchester. Tues., 6 May, 6.15 p.m.

Institution of Mining and Metallurgy

LONDON
Annual General Meeting (open only to corporate and non-corporate members of the Institution), at 4 p.m. Tea at 4.30 p.m. Presidential Address on "Productivity," by J. B. Dennison, at 5.15 p.m. Geological Society, Burlington House, Piccadilly, W.1. Thurs., 15 May.

Institution of Production Engineers

BIRMINGHAM
"Product Design," by R. Cantor. Midlands Region. James Watt Memorial Institute, Great Charles Street, Birmingham. Tues., 13 May, 7 p.m.

Institution of Public Health Engineers

LONDON
Informal Discussion. Caxton Hall, off Victoria Street, S.W.1. Mon., 5 May, 6 p.m.
"Discharge of Sewage and Industrial Wastes into Estuaries," by Dr. B. A. Southgate. Caxton Hall, off Victoria Street, S.W.1. Thurs., 15 May, 6 p.m.

Junior Institution of Engineers

BIRMINGHAM
"Protective Relays," by H. S. Lewis. Midland Section. James Watt Memorial Institute, Great Charles Street, Birmingham. Wed., 7 May, 7 p.m.

Newcomen Society

LONDON
Third Dickinson Biennial Memorial Lecture: "Sixty Glorious Years—The Impact of Engineering on Society in the Reign of Queen Victoria," by Dr. S. B. Hamilton. Wed., 14 May, 6 p.m.

Physical Society

LONDON
"Free Radicals," by Dr. G. J. Minkoff. Low Temperature Group. Royal School of Mines, Prince Consort Road, South Kensington, S.W.7. Thurs., 8 May, 4 p.m.

Royal Aeronautical Society

LONDON
46th Wilbur Wright Memorial Lecture: "Automatic Flight—The British Story," by G. W. H. Gardner. Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, S.W.1. Thurs., 15 May, 6 p.m.*

Royal Institution

LONDON
"The Royal Institution and the Teaching of Science in the Nineteenth Century," by Edward Ironmonger. Wed., 14 May, 9 p.m.

Royal Meteorological Society

LONDON
"Progress in Atmospheric Pollution Research," by C. J. Regan; "The Introduction of Smoke Control Areas," by Dr. W. C. Turner; "Climatological Aspects of Air Pollution," by R. G. Veryard; and "Radioactivity in the Atmosphere: Its Origin and Measurement," by N. G. Stewart. Joint Meeting with the National Society for Clean Air. Agricultural House, Knightsbridge, S.W.1. Tues., 13 May, 4.30 p.m.

Royal Society

LONDON
"The Institute of Aviation Medicine": a lecture by Group-Captain W. K. Stewart. Thurs., 29 May, 4.30 p.m.*

Royal Society of Arts

LONDON
"British Trade and Commerce: Part III—With Western Europe," by Roger Falk. Wed., 7 May, 2.30 p.m.
"Ghana," by Edward O. Asafu-Adjaye. Thurs., 8 May, 5.15 p.m.*

Society of Instrument Technology

LONDON
"Control of the Radio Telescope," by Dr. J. G. Davies. Manson House, Portland Place, W.1. Thurs., 8 May, 7 p.m.*

South Wales Institute of Engineers

CARDIFF
"Staple Pit Bunkerage versus Other Types of Bunkerage," by G. Blackmore. Thurs., 15 May, 6 p.m.

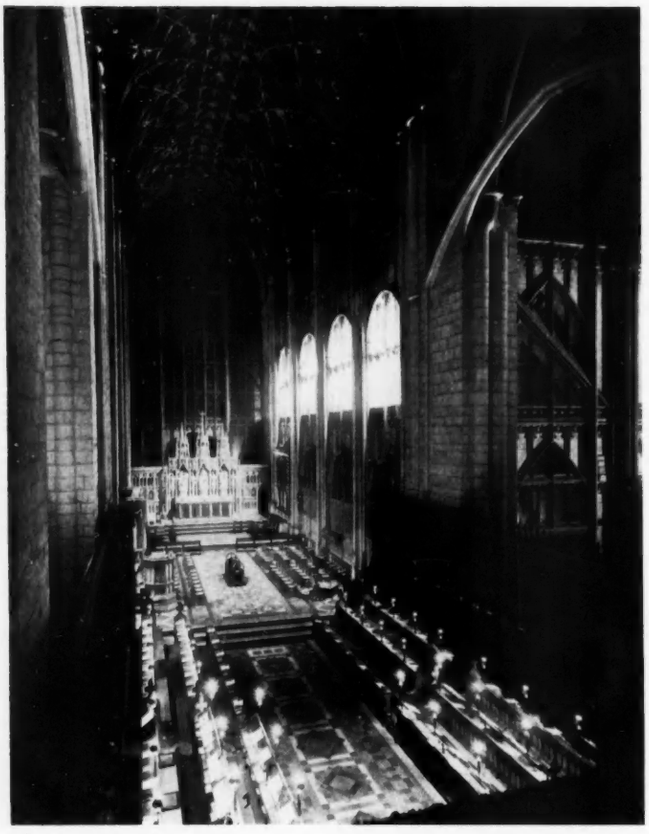
The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than three weeks before the date of the meeting.

*** An asterisk is placed where it is understood that refreshments are available prior to the time stated.**

Association of Supervising Electrical Engineers, 23 Bloomsbury Square, London, W.C.1. (LANgham 5927.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Combustion Engineering Association, 6 Duke Street, St. James's London, S.W.1. (WHItehall 5536.)
Helicopter Association of Great Britain, 4 The Sanctuary, London, S.W.1. (ABBey 5160.)
Illuminating Engineering Society, 32 Victoria Street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 12 The Parade, Solihull, Warwickshire. (Solihull 1111.)
Institute of Fuel, 18 Devonshire Street, Portland Place, London, W.1. (LANgham 7124.)
Institute of Petroleum, 61 New Cavendish Street, London, W.1. (LANgham 3583.)
Institute of Road Transport Engineers, 69 Victoria Street, London, S.W.1. (ABBey 6248.)
Institution of Civil Engineers, Great George Street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Mining and Metallurgy, 44 Portland Place, London, W.1. (LANgham 3802.)
Institution of Production Engineers, 10 Chesterfield Street, London, W.1. (GROsvenor 5254.)
Institution of Public Health Engineers, 118 Victoria Street, London, S.W.1. (VICtoria 3017.)
Junior Institution of Engineers, Pepys House, 14 Rochester Row, London, S.W.1. (VICtoria 0786.)
Newcomen Society, Science Museum, Exhibition Road, London, S.W.7. (KENsington 1793.)
Physical Society, 1 Lowther Gardens, South Kensington, London, S.W.7. (KENsington 0048.)
Royal Aeronautical Society, 4 Hamilton Place, London, W.1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle Street, London, W.1. (HYDe Park 0669.)
Royal Meteorological Society, 49 Cromwell Road, South Kensington, London, S.W.7. (KENsington 0730.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2. (TRAfalgar 2366.)
Society of Instrument Technology, 20 Queen Anne Street, London, W.1. (LANgham 4251.)
South Wales Institute of Engineers, Park Place, Cardiff. (Cardiff 23296.)

Design

"DESIGNED APPEARANCE" LIGHTING IN GLOUCESTER CATHEDRAL



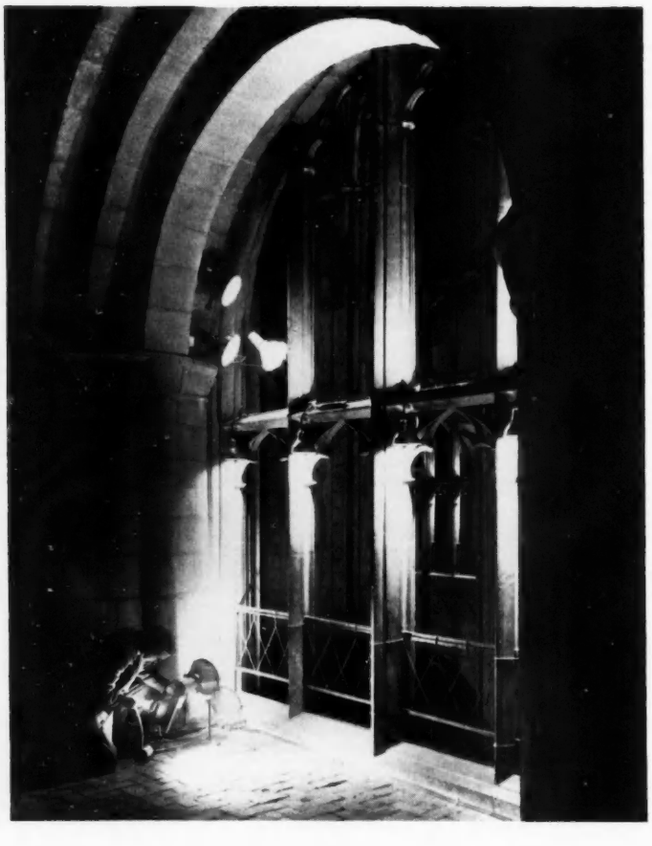
To be effective, lighting requires to be carefully planned, and when the subject is Gloucester Cathedral the complexities—and possibilities—are greatly increased. First the lighting must of course bring out the architectural beauties; second it must be enough to enable worshippers to see their books; and third it must be sufficiently flexible for practical use, for all the building is rarely in use at the same time.

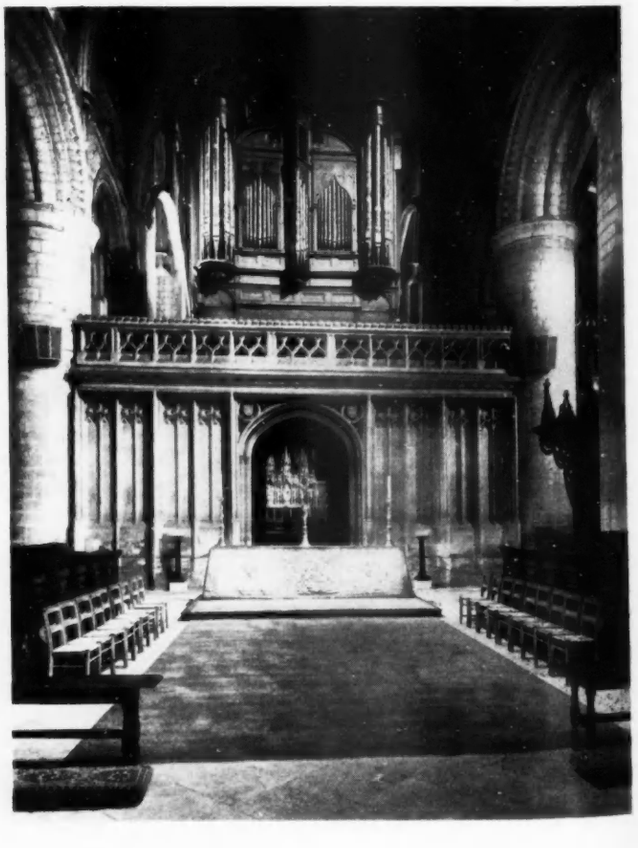
Consequently, when it was decided to renew the 50-year-old installation, Drake and Gorham Limited, the contractors, co-operated with the General Electric Company Limited to produce a scheme using the latter's "Designed Appearance System." This technique is not confined to any particular system of lighting and can be applied to buildings that are as yet only on the drawing board. The procedure in this case started with photographing the interior both from the "receiving" and "delivering" points of view, and calculating the reflecting properties of the various materials. The information so obtained was then translated into terms of light direction and intensity, and so to the detail choice of each unit and its site. Floodlights, striplights and spot lights have all been incorporated. Moreover, all materials have been chosen to last for at least 100 years.

The supply is received from the three-phase system by underground cable entering the crypt and terminating at a main switchboard which provides a cubicle to house the supply authority's metering equipment. At this point the whole installation, with the exception of maintained services to the heating system, is controlled by contactor switchgear which can be operated from the main entrances and the sub-control point.

The control of the lighting installation is by means of a specially designed switch panel which also contains all sub-circuit fuses at one position. By means of this panel it is possible to preset the desired lighting arrangement, which can then be extinguished and brought into use by means of the main contactor. When a service is held in the choir or Lady Chapel, only the south aisle in the nave need be lighted, with the altar lit at reduced level, or with the altar, organ and screen lit. Similarly, when the choir is used for small services the lighting there can be confined to the

Lighting a cathedral offers special problems. The choir (left) is lit by individual lamps and by mass lighting from the triforium (below, left). The organ (below, right) is left darker as a contrast to the nave altar.





desk lights and the east face of the organ, and the High Altar is on reduced lighting. By varying the extent of the lighting system, many different and beautiful effects can be obtained. This method also ensures that all unwanted lights can be switched out and the wiring made dead on leaving the building.

The whole of the wiring has been carried out with mineral-insulated copper-sheathed cables fixed to the surface of the stonework by means of non-ferrous clips, screws and wall plugs. The routes have been carefully selected to provide for hiding the cables from sight wherever possible; for the rest some careful camouflage has been employed. The total loading of the new system is 40·7 kVA and does not exceed that of the old.

The Designed Appearance of the cathedral is effected mainly by concealed lighting fittings and projectors, but decorative wrought iron desk lights, made by Gloucestershire craftsmen, have been provided for the choir, because they present the most appropriate appearance for services attended by small congregations.

A coherent drift of light is provided from south to north across the cathedral to reveal the shapes of the stonework, particularly the nave columns and choir. The nave altar and High Altar, as the principal objects of regard, are fully emphasised. The High Altar and reredos, which are seen at a distance, are both strongly modelled, and fairly strong modelling is used for the screen, and for the organ which is left darker than the choir beyond it. Other lights reveal gently the tracery of the east window and the aspiring height of the choir vault.

The drift of light from south to north results in the north nave arcade wall and north aisle wall being brighter than the south arcade and south aisle wall, and the north wall is made brighter than the north arcade, to reveal the full width of the structure. The same direction of light is carried through in the transepts, which are brighter than the aisles, and the tracery which separates them is seen from the aisles in silhouette. Three monuments of special interest are lighted by concealed fittings leaving darker spaces between them.

Main lighting equipment in the nave is mounted on the triforium and, in some instances, on the clerestory. The aisles are lighted from the capitals of engaged columns on the south wall and from the capitals of the main columns on the north side. In the choir, lighting equipment is installed in the openings of the large triforium, where a variety of fittings is placed. The fittings are enclosed where necessary to prevent interference. " Striplite " lamps lighting upwards ensure that the whole of the openings appear to be lighted. Lights for the south transept are mounted in the choir triforium, most of them being concentrated in a small gallery on the south side. The north transept is lighted by equipment mounted on the back of the choir stalls.

The majority of the lighting is carried out with a single type of projector designed specially for the purpose. Its features include provisions for fixing and aiming it in awkward situations, and for clamping it securely and maintaining it easily without disturbing its aim, focus, or the settings of louvres or spreaders.

For maintenance, the whole reflector and lamp assembly can be removed and replaced accurately in position without disturbing any of the settings. The installation work was carried out mainly by only two men and occupied about 5,200 working hours over a period of two years. A total route length of about 4 miles and a total conductor length of over 13 miles were involved.

DESIGN DEMANDS OF THE BALLISTIC VEHICLE

A lecture on " Guided Weapons and Aeronautics " was given recently before the Royal Aeronautical Society by Dr. R. Cockburn, C.B., O.B.E., controller of guided weapons and electronics, Ministry of Supply. After discussing the effect of nuclear weapons on military strategy and how the requirement for annihilation, rather than attrition of, the target has led to the development of highly specialised weapons, the lecturer turned to the development of the defensive guided weapon and the ballistic missile, and the role of the manned aircraft. We give below an extract of the part of Dr. Cockburn's paper dealing with ballistic missiles and satellites.

The outstanding characteristic of the ballistic missile is its independence of the external environment. Control and guidance can be entirely self-contained and, after the initial launching phase, the missile continues on an invariable ballistic trajectory until it re-enters the atmosphere.

The missiles now becoming available are single-stage weapons using a bi-fuel liquid motor directly derived from the German V.2. It may be thought somewhat remarkable that 15 years have elapsed since the Germans first demonstrated the military possibilities of the ballistic missile and yet they are only just coming into service and have still to establish their reliability. However, the V.2, although a tremendous technical *tour de force* at the time, was of elementary design by present standards. It weighed about 12 tons and delivered about one ton of high explosive over distances not exceeding 200 miles with an accuracy of about 5 miles.

Current weapons have at least ten times the range and ten times the accuracy of the V.2, their thrust is of the order of 100 tons, and the structure weight is of the order of 3 per cent of all-up weight. Design of large rocket motors is still at an early stage and we must expect a period of technical improvement directed towards higher specific impulse, better control and, above all, greater reliability. Specific impulse is an even more critical parameter for the rocket motor than it is for aircraft engines, since the range of ballistic missiles depends on the square of the specific impulse instead of directly, as for aircraft. Control of thrust is also desirable since it allows excessive accelerations to be avoided, with a consequent easement in the design of the structure and of the delicate control components; and it permits the maximum range to be extracted from a given quantity of fuel and oxidant. Improvements in reliability and in readiness are necessary before the ballistic missile can be regarded as an entirely dependable weapon. It is in these respects that solid propellants offer promise for the future.

Structure weight is, as always, a critical design factor but here again the effect on range is more severe than for aircraft and the requirements correspondingly more stringent. The ratio of structure weight to all-up weight of the missile is an order of magnitude less than for aircraft. This calls for a completely new approach involving, for instance, pressurisation as a structural method.

However, by far the biggest challenge lies in the accuracy demanded of the guidance system, which moreover must be maintained under extreme conditions of vibration and acceleration. The performance required of the inertia components brings us to the very limit of instrument techniques. As an indication of the refinement of design, a deviation of the centre of gravity of a gyroscope by only a few wavelengths of light can lead to an error of several miles at the end of the trajectory.

Finally, there is the problem of re-entry. A long-range ballistic missile or a satellite must dissipate a large amount of energy as it plunges into the atmosphere. Most of this is left behind in the wake, but the small proportion left over is still very large and can heat up the missile to very high temperatures. As an example, a spherical satellite of about 1,000 lb in weight and a specific gravity of 3 reaches, during re-entry, a temperature of 2,000° absolute and a luminosity comparable with full moon. Very special measures are needed to ensure that equipment survives the high temperature and high accelerations arising during re-entry.

As is so often the case, all these problems, which at first appeared so formidable, have turned out to be solvable, and intercontinental ballistic missiles of sufficient range and accuracy are clearly on the verge of achievement.

The operational value of the ballistic weapon lies in its superiority over foreseeable defences, and in its relative invulnerability to counter-attack. This is likely to be the dominating factor for at least the next decade. The second advantage of the ballistic missile is that the entire launching site can be underground, protected from anything other than a direct hit with a nuclear weapon. Initially, security will lie in the difficulty of identifying and precisely locating these bases; but even when they become known, the accuracy of guidance, while adequate for attacking areas such as cities and even aerodromes, is unlikely to guarantee a direct hit on a buried launching site. When the deterrent is based on the ballistic missile rather than aircraft, its defence will involve much smaller resources than at present.

It will be a long time before man can venture into outer space with a reasonable chance of safe return and we may have to wait for new forms of energy before the wilder conjectures of science fiction become realisable; but even with chemical fuels, some of the next steps can be identified with reasonable confidence.

Kerosine and liquid oxygen, which are typical of present liquid propellants, burn at about 3,400° absolute and the exit velocity of the gases is about 1½ miles per sec. If 90 per cent of the weight is fuel, and less than 10 per cent is structure and payload, the final velocity can be built up to about twice the gas velocity, i.e., 3 miles per sec. This will allow a missile, if fired straight up, to reach a height of about 1,000 miles above the earth, or if fired on an optimum trajectory to achieve a range of about 2,000 miles.

Greater velocities can be built up by using multi-stage rockets. A three-stage missile, for instance, allows 99 per cent of the initial mass to be expended in building up the momentum of the remaining 1 per cent; in this way the velocity of 5 miles per sec required for a satellite can be achieved. To escape altogether from the earth's gravitational field requires a velocity of 7 miles per sec, and with present specific impulses and structural methods would demand a take-off weight at least a thousand times the final weight.

In terms of the high-grade technical effort involved, these are very large undertakings and may well prove to be beyond the resources of any one country. However, we should not feel too intimidated by the task of launching such huge missiles. The chemical energy dissipated as high explosive in one bomber raid during the last war is not a high price to establish a satellite in an orbit for several years, or to land a beacon on the moon. Such ventures would undoubtedly stimulate technical progress throughout industry, but they must be justified by the amount of new knowledge acquired. The problems of elaborate telemetry over a long period, and of controlled recovery, are certainly solvable with the resources available in the electronic and aeronautical industries. There is no doubt that mankind is on the threshold of a fascinating new adventure; the extent to which this country can afford to contribute is, of course, another matter.

XUM

Continuing **Design**

MACHINE TOOL CHATTER*

Effect of Flexibility in Machine and Foundation

By W. Fishwick, PH.D.,† *and S. A. Tobias*, D.SC., PH.D.‡

Over a period of years the application of flexible supports has frequently been advocated. Two types of flexible supports have been suggested: (1) *vibration isolator units*, developed originally for the reduction of transmitted vibrations from internal combustion engines, railway carriages, etc.; (2) *flexible supporting layers* made from various materials. It is claimed that for machine tools these flexible supports have two main advantages. First, owing to their low stiffness negligible vibration is transmitted to and from the foundation and so the general vibration and noise level in the workshop is reduced. Second, when these isolators are attached directly to the machine tool structure the preparation of special foundations, or even the use of foundation bolts, becomes superfluous and thus any reorganisation of production lines is facilitated.

To those concerned with the theory of vibrations these advantageous consequences seem obvious enough. However, the effect of flexible supports on the propensity of a machine tool to chatter during cutting does not seem to have been realised or at least has not been studied. The foundation beneath a machine tool constitutes the end conditions to a complex elastic structure. Any variation in damping capacity of the supports will, therefore, affect the damping of all the modes of vibration of the structure. Chatter occurs when conditions at the cutting edge of the tool are such as to overcome the damping of some particular mode, and it is known from previous work that self-sustained chatter tends to occur when damping is small and/or the dynamic stiffness is small. It may be, therefore, that indiscriminate use of flexible supports may result in a workshop with a low level of noise transmitted through the floor but where most machines chatter when cutting.

This article sets out to examine the effect of flexible supports on the modes of vibration of a machine tool and attempts to find out whether flexible supports can be used for vibration isolation without causing a machine to chatter. It will be assumed that an attempt is being made to realise both advantageous consequences mentioned before and that consequently the internal damping of the flexible supports is relatively small and that they are directly attached to the machine tool structure.

SIMPLE EQUIVALENT SYSTEMS

A machine tool is a complex elastic structure with many possible modes of vibration, but the ones of interest here are those that can be excited by the application of a periodic force between tool cutting edge and workpiece. If a periodic force of constant amplitude but variable frequency is applied at these points and the amplitude of the resulting periodic vibration is measured we can plot out the frequency response curve relating vibration amplitude to applied frequency. This response curve will have many resonance peaks as illustrated in Fig. 1.

These resonances are usually well separated and the frequency response curve in the neighbourhood of a resonance peak resembles that obtained with a simple mass-spring system having viscous damping. For many purposes, therefore, the structure can be simulated by a collection of damped mass-spring systems, each of which resonates at one of the resonance frequencies of the real structure. Usually one of these peaks is less damped than its neighbours and is the one which leads to chatter.

When chatter occurs the force set up between tool and workpiece, which is a function of the vibration amplitude and velocity as well as tool speed and other factors, is such that the inherent damping of one of the modes is overcome and an oscillation is sustained at a frequency not far from the resonance frequency of the mode. This has been shown in two previous papers (1)§ and (2). If the mode damping is high enough this tendency to chatter is suppressed.

Suppose now that the machine is represented by a mass m_1, and spring of dynamic stiffness λ_1 and damping coefficient d_1. The machine is not isolated in space but rests on a foundation, which itself has elastic and damping properties. Now only the base of the machine rests on the foundation so that only some of its vibrating elements are affected. These will lose energy into the foundation and the local elastic restoring forces will be increased. The effect on the original mode of vibration will be to alter it somewhat, to change its resonant frequency and to alter the damping. This effect can be represented by adding to m_1 a small mass m_2 and by placing a spring of stiffness λ_2 and damping d_2 in parallel with λ_1. Fig. 2 represents a particular mode of the machine tool acted upon by a force P; x is the resulting deflection.

The somewhat indeterminate but small mass m_2 arises from the fact that ground under forced vibration has some of the properties of a mass-spring system itself. The resonance frequency of m_2 and λ_2 will normally be higher than the frequencies of chatter. The force transmitted to the foundation by vibration will be proportional to that exerted by λ_2 and d_2.

All of the parameters of the model can be allocated precise values from the shape of a simple resonance curve and the deflection at the resonance peak. Experiment will give these overall quantities, for the machine will be resting on its foundation during the experiment. If only relative rather than absolute deflections are known, then it is perhaps permissible to allocate to λ the dynamic stiffness of the machine measured between tool and workpiece. The effect of λ_2 is usually not large and the main effect of the foundation is to increase the damping of the mode from d_1 to $d = d_1 + d_2$; m_2 will be small compared to m_1.

EFFECT OF A FLEXIBLE SUPPORT ON DAMPING BY THE FOUNDATION

When a vibration isolator or a flexible layer is inserted between the machine and original foundation, then its elastic and damping properties appear in *series* with those of the ground. The flexible support can be represented by a spring of stiffness λ_3 and damping coefficient d_3. The support and foundation can be represented approximately by the model of Fig. 3 (*a*).

The system of Fig. 3 (*a*) can easily be analysed, if we put

$$x = X \cos \omega t = \mathrm{Re}\{ X e^{j\omega t} \}$$
$$F = F_0 \cos \omega t = \mathrm{Re}\{ F_0 e^{j\omega t} \}$$

Then the complex ratio between amplitudes F_0 and X is

$$\frac{F_0}{X} = \frac{(\lambda_3 + j\omega d_3)(\lambda_2 - m_2\omega^2 + j\omega d_2)}{\lambda_2 + \lambda_3 - m_2\omega^2 + j\omega(d_2 + d_3)} \quad . \quad . \quad (1)$$

If m_2 is negligible as depicted in Fig. 3 (*b*), then

$$\frac{F_0}{X} = \frac{(\lambda_3 + j\omega d_3)(\lambda_2 + j\omega d_2)}{\lambda_2 + \lambda_3 + j\omega(d_2 + d_3)} \quad . \quad (2)$$

These expressions can be split into real and imaginary parts which can then be interpreted as an equivalent damped spring, the elements of which are frequency dependent. The expressions are cumbersome and it is sufficient for our purposes to make some approximations. For very low frequencies

$$\frac{F_0}{X} \simeq \frac{\lambda_2 \lambda_3}{\lambda_2 + \lambda_3} \quad . \quad . \quad (3)$$

and since $\lambda_3 \ll \lambda_2$, then $\frac{F_0}{X} \simeq \lambda_3$. At very high frequencies equation (1) reduces to

$$\frac{F_0}{X} \simeq j\omega d_3 \quad . \quad . \quad . \quad (4)$$

and equation (2) reduces to

$$\frac{F_0}{X} \simeq j\omega \frac{d_2 d_3}{d_2 + d_3} \quad . \quad . \quad (5)$$

A simple damped spring λ, d would reduce to λ at low frequencies and $j\omega d$ at high frequencies, so we can draw the somewhat obvious conclusion and approximate the complex system of Figs. 3 (*a*) or 3 (*b*) by a simple damped spring of constants

$$\lambda_4 \simeq \frac{\lambda_2 \lambda_3}{\lambda_3 + \lambda_2} \quad . \quad . \quad . \quad (6)$$

and

$$d_4 \simeq \frac{d_2 d_3}{d_2 + d_3} \text{ or } d_3 \quad . \quad . \quad . \quad (7)$$

The point to note is that the effective damping applied to the machine structure is reduced, for $\frac{d_2 d_3}{(d_2 + d_3)} < d_2$, and in a practical case $d_3 < d_2$

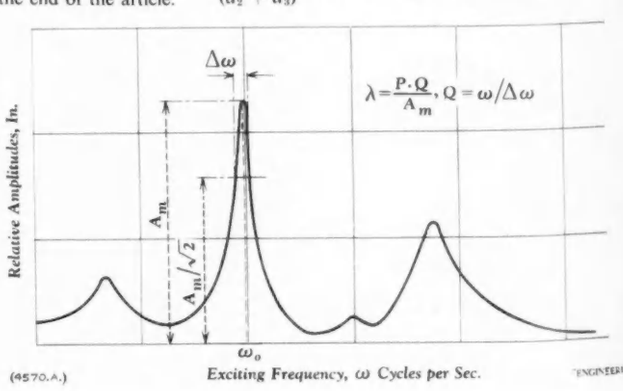


Fig. 1 Resonance curve of relative amplitudes between cutting edge and workpiece.

§ References are given at the end of the article.

* This article is an extended version of a paper read at the "Second Colloquium for Machine Tool Research and Design" (2.FoKoMa) held at the Technische Hochschule, München, 1955.

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‡ Assistant Director of Research, Department of Engineering, Cambridge University.

so that this remark holds for either form of equation (7). In fact the first form of equation (7) is a better approximation for frequencies below $\sqrt{\frac{\lambda_2}{m_2}}$. Any value of d_3 which is practical will reduce the machine damping and hence enhance the resonance peak of the mode.

For effective vibration isolation both λ_3 and d_3 should be small, but this on the other hand may set the machine into oscillation during cutting There is no obvious way out of this dilemma. If the machine shows no tendency to chatter under current working conditions and it is necessary to isolate it, only experiment will show to what extent the damping of the machine can be reduced. If the machine is known to chatter under certain working conditions then vibration isolating units will probably make matters worse. However, it may be possible to introduce a layer of flexible supporting material so that the machine damping is increased. From our foregoing discussion this would not seem possible but in our discussion we tacitly assumed that the area of contact between flexible layer and machine is the same as that between the original floor and the machine. If, however,

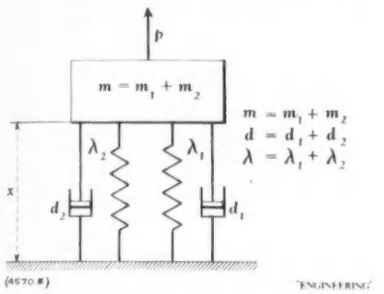

Fig. 2 (left) Equivalent system of machine tool structure resting on foundation.

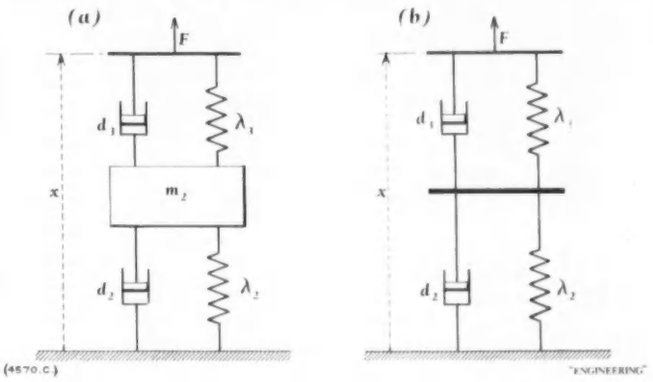

Fig. 3 (right) Equivalent system of machine tool structure on flexible supports.

the isolating material can be used to give a very much increased area of support to the machine so that when in vibration more elements of the structure can lose energy then, in fact, the overall damping may be increased.

It is suggested that the apparent increase in damping of some machines when mounted on a thin layer of cork or other material is due to the possibility of more elements in the structure losing vibrational energy to the foundation. It follows also that machines should be designed with large surfaces which can be bolted down in contact with the foundations.

FLEXIBLE SUPPORTS AND REGENERATIVE CHATTER

From the foregoing considerations, the application of flexible supports does not appear to be promising in the case where chatter danger exists. However, there is a type of chatter in which dynamic instability is confined to certain rotational speed bands of the tool or the workpiece. As has been shown by the authors in a previous paper (Ref. 1), the numerical value of these chatter speed bands is determined by the natural frequency of the mode of vibration, the damping of which is below a critical level. Consider now a special machine which has only one rotational speed. It may occur that this speed falls into one of the chatter speed bands of the machine owing to the fact that one particular natural frequency of the machine possesses the required value. By shifting the particular natural frequency to a different value, the chatter speed bands are also shifted. Under suitable conditions, it may be possible to shift the chatter speed bands in such a way that the rotational speed of the tool falls into a stable (chatter-free) speed band. Whether this shift of the speed bands can be achieved by the application of flexible supports depends on the mode of vibration to which it belongs. In general, flexible supports have the greatest effect on the lowest mode of vibration. This mode corresponds to a rocking motion of the machine on the foundation and the use of flexible supports will decrease its natural frequency, resulting in a lowering of the critical speed bands. The natural frequencies of the higher modes are little affected by the end conditions of the structure. Thus, if it is the lowest mode of vibration which is being excited when chatter occurs the application of flexible supports may have beneficial effects in spite of the fact that their use probably involves a decrease of the damping of the system.

The above remarks can be explained in more detail by examining some experiments carried out with radial drilling machines. The conclusions can be applied also to other types of machines provided that the type of chatter existing is of regenerative nature.

The resonance curve of the machine in question when standing directly on wood-block floor, measured as previously explained, is shown by the full curve of Fig. 4. In the frequency range investigated the structure had two natural frequencies at $\omega_0 = 10{\cdot}2$ cycles per sec and at $\omega_0 = 26$ cycles per sec. When excited at $\omega = 10{\cdot}2$ cycles per sec the structure performed a rocking motion on the foundation and so this mode is called *rocking mode*. At $\omega = 26$ cycles per sec the motion of the structure resembles that of a tuning fork and consequently it will be referred to as *tuning fork mode*. The rocking mode is only lightly damped and its dynamic amplification factor (*c.f.* Fig. 1) is $Q = 14{\cdot}5$. The damping of the tuning fork mode is large, its dynamic amplification factor being $Q = 3{\cdot}7$.

The machine was now placed on vibration isolator units* and the resonance curve indicated by the dotted line in Fig. 4 was obtained. The natural frequency of the rocking mode has decreased to $\omega_0 = 2{\cdot}2$ cycles per sec (not shown on the figure) with an estimated $Q \simeq 14{\cdot}0$. The natural frequency of the tuning fork mode is $\omega_0 = 27$ cycles per sec and its dynamic amplification factor $Q = 30{\cdot}5$.

The chatter behaviour of the machine on the two different types of support will now be investigated by the stability charts corresponding to the particular machining conditions, as explained earlier. That is, it is assumed that each mode can be represented by an ideal mass-spring system and then from the resonance curves the values ω_0, λ and Q can be calculated (*c.f.* Fig. 1).

Associated with a particular working condition (cutting speed, feed, tool geometry, workpiece material, etc.) there are two parameters, k_1 and K, which can be determined experimentally. In this way the ratios $\frac{k_1}{\lambda}$ and $\frac{K}{\lambda}$ are obtained. In this example we shall assume $k_1 = 3{\cdot}25 \times 10^5$ lb per in and $K = 0{\cdot}94 \times 10^4$ lb per in and so the values tabulated in Table I are obtained.

As explained elsewhere (Refs. 1 and 2), there is associated with each mode of vibration and cutting parameters k_1 and K a stability chart of which the co-ordinates are dynamic magnification Q and relative tool speed $\frac{\Omega}{\omega_0}$. The chart contains regions marked stable and unstable on one side of a line, the Q_m line, and a region of unconditional stability on the other side of this line. If a given mode of vibration has a certain structural effective $Q = Q_e$ then a horizontal line at ordinate Q_e drawn on the chart might intersect the unstable areas and so indicate the speed ranges in which regenerative type chatter may be expected. If the Q_e line lies below the Q_m contour then regenerative chatter is not possible at any speed. The shape of the chart depends on $\frac{k_1}{\lambda}$, $\frac{K}{\lambda}$, and the ordinates Q of the stability boundaries drawn on the chart are described by a function of the form

$$Q\,\frac{k_1}{\lambda} = f\left(\frac{k_1}{K}, \frac{\Omega}{\omega_0}, \frac{k_1}{\lambda}\right)$$

Strictly speaking for each mode or set of parameters there is needed a separate chart but fortunately the quantity $\frac{k_1}{\lambda}$ enters the function f very nearly in the form $1 \pm \frac{2k_1}{\lambda}$ and so for small values of $\frac{k_1}{\lambda}$ and provided the variation in $\frac{k_1}{\lambda}$ from mode to mode is not very large we can for qualitative investigation draw only one chart for an average value of $\frac{k_1}{\lambda}$, i.e. for an average value of $\frac{1}{\lambda}$ since k_1 is independent of the mode. However, the left-hand side of the above equation is $\frac{Q\,k_1}{\lambda}$ and so if λ' is the average value of the dynamic stiffness, assumed the same for each mode, we must replace the mode structural Q_e by a reduced value $Q_e' = Q_e \frac{\lambda'}{\lambda}$ where λ is the true value for the mode.

It must be pointed out that the resulting stability chart will not yield the unstable speed bands accurately. However, the inaccuracies

* The vibration isolators used were originally developed for railway carriages and similar applications.

TABLE I.—*Comparison of Chatter Behaviour with Machine on Floor and on Isolators.*

		ω_0 cycles per sec.	$\lambda \times 10^5$ lb per in.	Q	$\frac{k_1}{\lambda}$	$\frac{K}{\lambda}$	Q'_e
Machine on floor	Tuning fork mode	26	2·4	3·7	0·135	0·039	1·7
	Rocking mode	10·2	0·75	14·5	0·44	0·128	22
Machine on isolators	Tuning fork mode	27	1·1	30·5	0·29	0·085	30·5
	Rocking mode	2·2	1·0 Estimated	14 Estimated	0·33	0·094	15·4

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introduced in this way are probably not appreciable compared with those which arise due to the uncertainty caused by the experimental determination of k_1 and K. These last two factors are found from cutting thrust measurements and, as is well known, the cutting thrust can vary greatly in successive tests under identical cutting conditions.

In the present case the average $\frac{k_1}{\lambda'} = 0{\cdot}3$, the

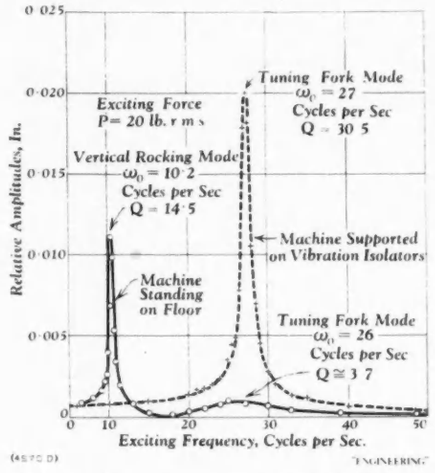

Fig. 4 Resonance curves of radial drilling machine.

$\leqslant 0{\cdot}465$ and $0{\cdot}528 \leqslant \frac{\Omega}{\omega_0} \leqslant 1{\cdot}36$, that is, 445 to 750 r.p.m. and 860 to 2,210 r.p.m. in the tuning fork mode (since $\omega_0 = 27$ cycles per sec); and $0{\cdot}29 \leqslant \frac{\Omega}{\omega_0} \leqslant 0{\cdot}46$ and $0{\cdot}54 \leqslant \frac{\Omega}{\omega_0} \leqslant 1{\cdot}32$, i.e., 38·3 to 60·7 r.p.m. and 71·3 to 174 r.p.m. in the rocking mode ($\omega_0 = 2{\cdot}2$ cycles per sec). The first unstable band of the rocking mode is only just excited and the friction of the tool would probably suppress chatter of this mode.

With the view of the following discussion it is convenient to plot the above determined unstable speed ranges with an abscissa equal to Ω r.p.m., as shown in Fig. 6. Suppose that when directly on the floor the machine's drill speed was 200 r.p.m. and so its speed fell into the second chatter band. After placing the machine on the vibration isolators this speed lies below the second band of the tuning fork mode and above the first band of the rocking mode and, as a result, chatter will not occur. In this case, the application of the vibration isolators has definitely desirable results. However, if originally the drill speed was 1,000 r.p.m. (lying above the first band) the application of the isolators would place this speed right into the first chatter band and chatter would result. It is also possible that originally the speed fell into a stable region and continued to do so after the use of the isolators.

From these considerations it will be clear that, depending on the dynamic characteristics of the structure and on the drill speed, the application of flexible supports may eliminate chatter but may also produce it in other circumstances. Basically similar considerations apply also to other types of machines provided that the lower modes of vibration are excited during chatter. When the higher modes of vibration are liable to chatter the application of flexible supports has relatively little effect on the damping and in that case the unstable speed bands before and after their application may be, more or less, identical. In such circumstances, the use of isolators may be entirely advantageous. However, the essential point of the present argument is that the mere fact that in some cases considerable improvements are achieved by the use of flexible supports does not prove that their application in other cases is sound. The authors have encountered cases when machines which cut badly on a solid foundation, worked completely chatter-free on a flexible support. However, exactly the opposite occurred in some other instances.

One of the difficulties in deciding whether in a certain situation flexible supports are beneficial or not is that the actual experimental results may be highly misleading. This will be seen from Figs. 7 and 8. Fig. 7(*a*) and 7(*b*) show some typical records of the relative vibration amplitude between drilling spindle and workpiece when the machine was resting on the floor and the drill speed was 350 r.p.m.

Neither trace represents chatter in the sense of the word used in the present article since the amplitudes were small and alternately build up and decay. As a matter of fact, this condition is usually encountered when the machine is near the threshold of stability, that is, in a condition which is represented by the boundary lines of the unstable regions of the stability chart. The chatter frequency was 11·8 to 12·1 cycles per sec and the greatest peak-to-peak amplitude 0·0012 in. Placing the machine on the isolators makes it very sensitive to unbalance vibrations which were previously not noticeable. This can be seen from Fig. 7(*c*) which shows the relative amplitude when the spindle was running but no drilling took place. Figs. 7(*d*) and 7(*e*) show the relative vibration when drilling with the application of flexible supports. The chatter frequency was 33 to 33·2 cycles per sec and the maximum peak-to-peak amplitude was 0·00065 in. This result appears to be highly satisfactory since the amplitude was halved.

An even more satisfactory conclusion might be drawn from Fig. 8 which shows the static and dynamic deflections between spindle and workpiece, commencing with the drill entering the workpiece (left side of Fig. 8(*a*) and Fig. 8(*c*)), the slowly increasing static deflection due to the increasing thrust and finally the full static deflection (measured from the thin horizontal line) and the superimposed chatter. The drill speed was 440 r.p.m. and so chatter in the real sense was present when the machine was resting on the floor (Fig. 8(*a*) and 8(*b*)). The chatter peak-to-peak amplitudes were 0·0017 in with 11·9 cycles per sec chatter frequency. When resting on the flexible supports (Fig. 8(*c*) and 8(*d*)) the maximum chatter peak-to-peak amplitude was 0·0009 in and the frequency 33·3 cycles per sec.

Although it might appear from Fig. 7 and Fig. 8 that the application of the isolators was advantageous, since it resulted in a drastic reduction of the chatter amplitude, this conclusion is wrong. It is almost certain that tool life is dependent primarily on the chatter velocity and not the chatter amplitude. Now, in the case of Fig. 7(*b*) (machine on the floor) the maximum chatter velocity was 0·007 in per sec and for Fig. 7(*e*) (machine on isolators) it was 0·010 in per sec. In the case of Fig. 8 the chatter velocity on the floor and on isolators was 0·010 in per sec and 0·015 in per sec, respectively. Clearly,

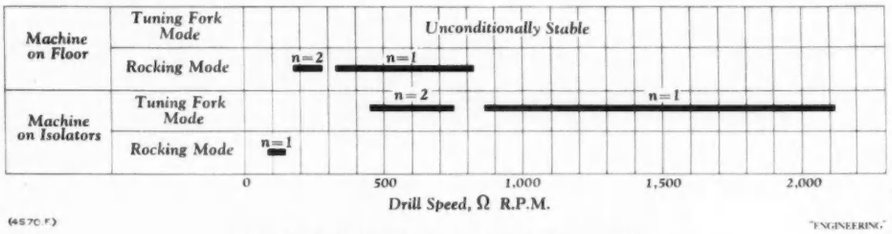

Fig. 5 Stability chart of radial drilling machine.

average $\frac{K}{\lambda'} = 0{\cdot}085$, and the value $\lambda' = 1{\cdot}1 \times 10^6$ lb per in. With these values the stability chart of Fig. 5 has been constructed. It will be noted that the Q_m line rises steeply at low values of $\frac{\Omega}{\omega_0}$, and so only two speed ranges or bands appear on the chart. The reduced values of Q_e' for the modes are 1·7, 22, 30·5 and 15·4, in the same order as in Table I.

Referring back to Fig. 4 it will be noted that the isolator has apparently reduced the Q of the rocking mode. Two reasons might account for this: (*a*) at 2·2 cycles per sec the force generator was unsuitable and so rather crude means had to be used to find Q_e and λ, (*b*) the mode is a property of machine tool and foundation and the presence of the isolator has altered the frequency and perhaps the form of the mode slightly.

By inserting the appropriate Q_e' lines in the stability chart we find the drill speed-bands over which chatter will occur under the postulated drilling conditions. As can be seen from Fig. 5 directly on wood-block floor the speed bands leading to instability of the rocking mode are $0{\cdot}28 \leqslant \frac{\Omega}{\omega_0} \leqslant 0{\cdot}46$ and $0{\cdot}533 \leqslant \frac{\Omega}{\omega_0} \leqslant 1{\cdot}345$, i.e. since $\omega_0 = 10{\cdot}2$ cycles per sec, chatter occurs when the drill speed is between 170 and 280 r.p.m. and 325 to 820 r.p.m. The tuning fork mode is unconditionally stable. With isolators the tuning fork mode can also be excited. The speed bands leading to instability are $0{\cdot}275 \leqslant \frac{\Omega}{\omega_0}$

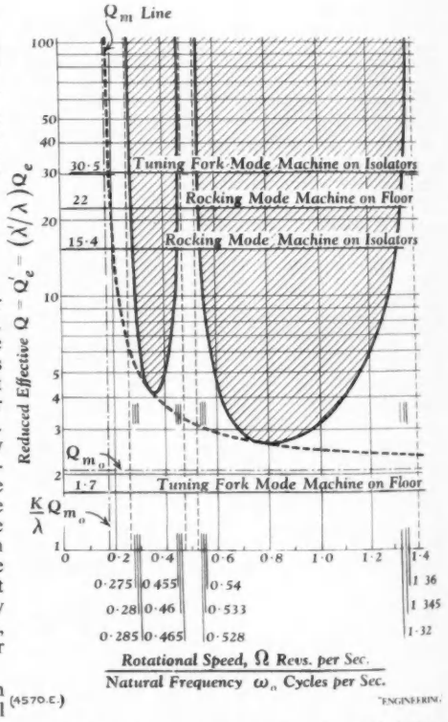

Fig. 6 Unstable speed bands of radial drilling machine when resting on floor and when supported by vibration isolators.

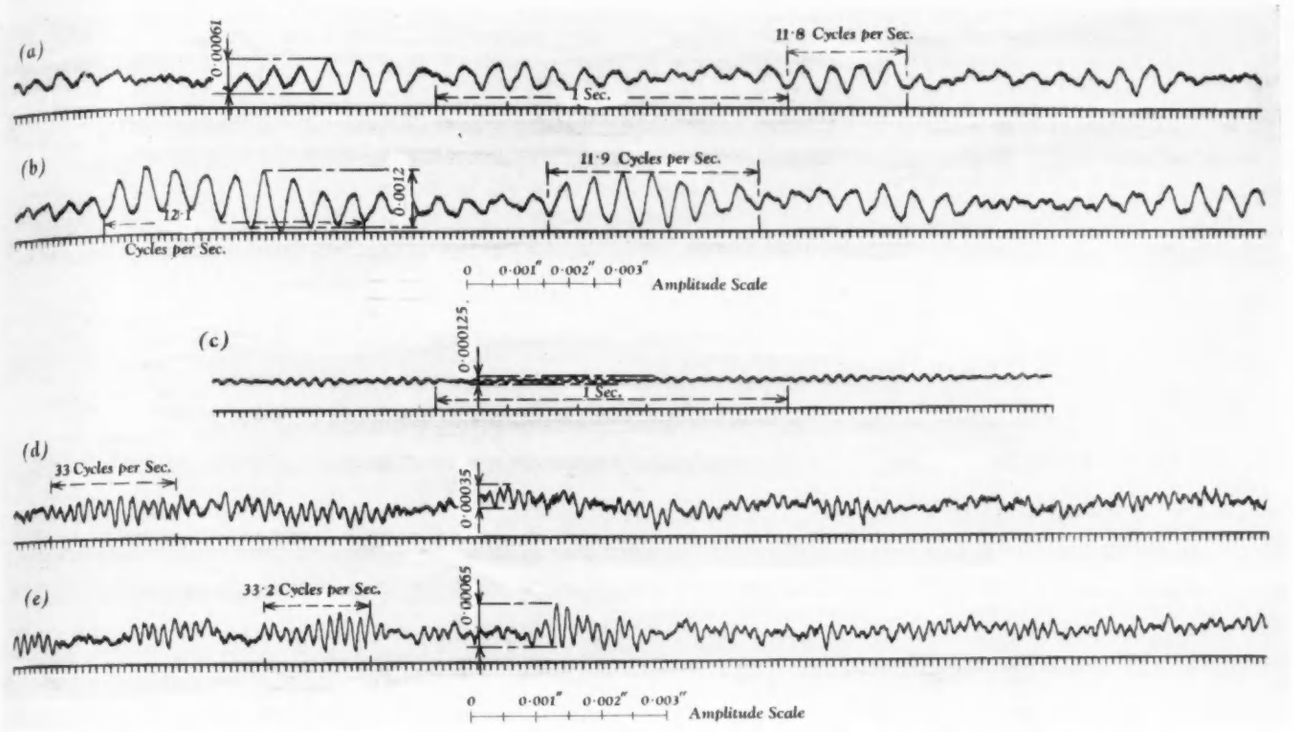

Fig. 7 Relative amplitude between workpiece and drilling spindle. (a) and (b), machine resting on floor; (c), unbalance vibrations when supported by isolators; (d) and (e), machine supported by isolators. Drill speed 350 r.p.m.

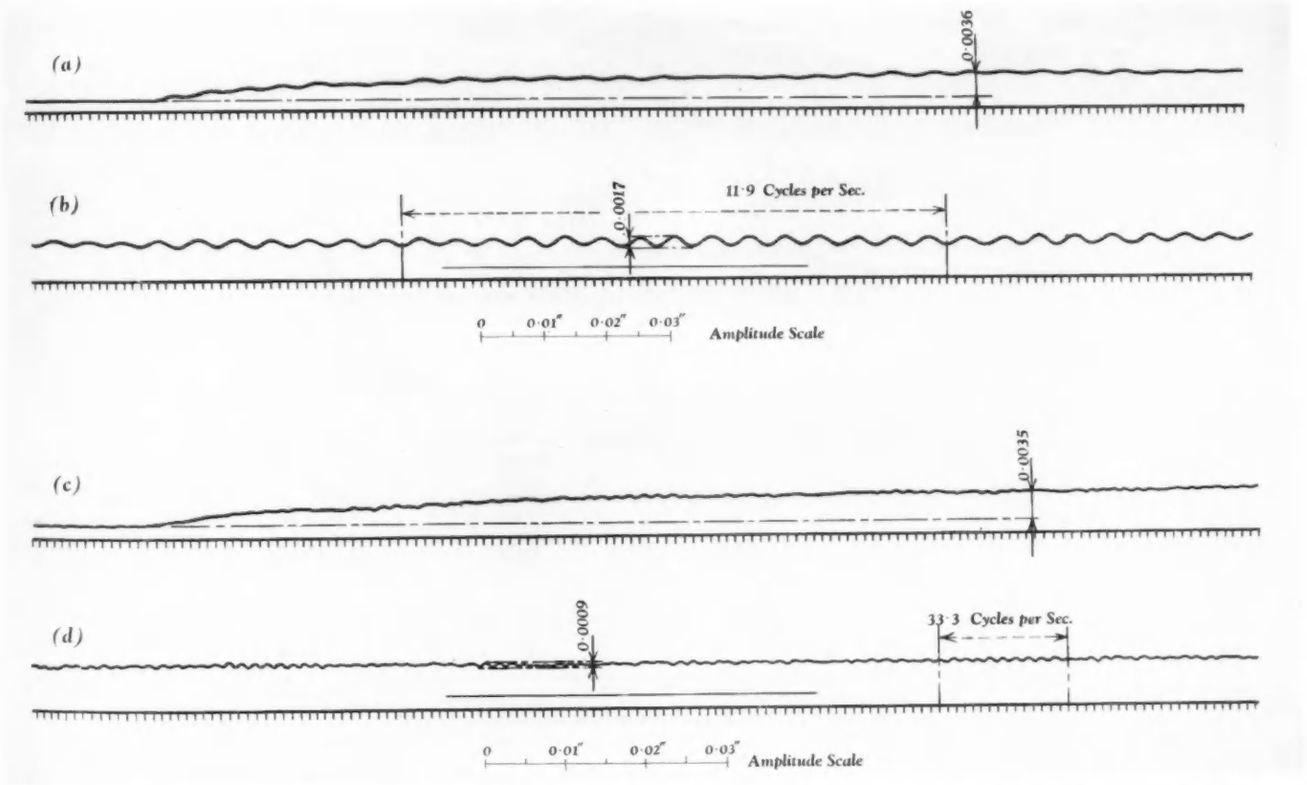

Fig. 8 Relative amplitude between workpiece and drilling spindle. (a) and (b), machine resting on floor; (c) and (d), machine supported by isolators. Drill speed 440 r.p.m.

if the decisive consideration was tool life the application of isolators would not be advised in this case. On the other hand, if the emphasis was on surface finish then flexible supports might be recommended. As a matter of fact, when resting on isolators, the machine drilled with surprisingly little vibration which could be detected by touch, over a wide speed range and with drills of greatly differing diameters. To all appearances, chatter was absent. However, this was entirely due to a decrease of the chatter amplitude and did not alter the fact that the chatter velocity had increased by about 50 per cent.

The reason for the decrease of the chatter amplitude, as shown in the two figures is that when the chatter frequency is high, with respect to the speed, additional damping is introduced by the elimination of the relief angle of the cutting tool. The drill flank comes into solid contact with the material after a certain amplitude has

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been reached. As a result, the amplitudes are limited but tool life suffers.

CONCLUSION

In general, a clear distinction has to be drawn between the application of *vibration isolator units*, such as those used for the isolation of internal combustion engines, and *isolating layers* of flexible materials. The damping capacity of the former is usually small and so, as it has been shown, their direct application entails a reduction of the damping. Their use may be beneficial when the machine is bolted to a large concrete block and this block is supported by the isolating units. However, this type of application is rather expensive and it implies that the second advantage of flexible supports, mentioned in the introduction, is automatically eliminated. The direct application of isolating units may be advantageous when in the type of machine under consideration only the higher modes of vibration are liable to cause chatter. As has already been mentioned, their damping is less affected by a decrease of the damping of the end conditions and so it is possible that the chatter behaviour of the machine remains, more or less, unaffected. It has been shown that there are instances when the use of isolating units results in a deterioration of the chatter behaviour, in the sense that the chatter speed bands are enlarged, but, at the same time, the chatter amplitudes being smaller an improvement of surface finish is achieved. In these cases the decision concerning the application of isolator units is dependent on a choice between tool life and surface finish.

Somewhat different conclusions apply to the use of isolating layers of flexible materials. It will be clear that from the point of view of chatter the material chosen should have a large damping capacity if the lower modes of vibration are liable to cause trouble. In this case the following general directives are likely to produce beneficial results:

(*a*) use the thinnest layer of isolating material which suffices, for the thicker the layer the more the damping is reduced;

(*b*) use all the supporting plates so that maximum energy is dissipated into the floor;

(*c*) it may be practicable to introduce auxiliary supports, by building up the workshop floor or other means, so that the thinnest layers of isolating material can be used over as large an area as possible.

From these considerations it will be clear that when the lower modes of vibrations are likely to cause chatter the direct application of isolator units or flexible supporting layers cannot result in an effective vibration isolation and an improvement of the chatter behaviour at the same time. Either the supports have a small damping and then isolation will be effective but chatter behaviour deteriorates, or their damping is large and then isolation is negligible but chatter behaviour improves. However, isolation without a deterioration of the chatter behaviour may be possible by the direct application of flexible sugports when only the higher modes of vibration are likely to cause chatter.

Acknowledgment.—The experimental part of this paper was carried out at the works of James Archdale and Company, Limited, Blackpole Works, Worcester.

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AIR MOTOR FOR HIGH TEMPERATURES

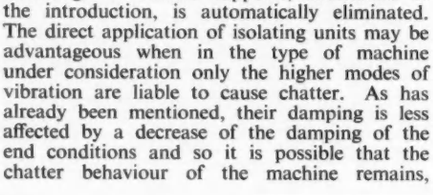
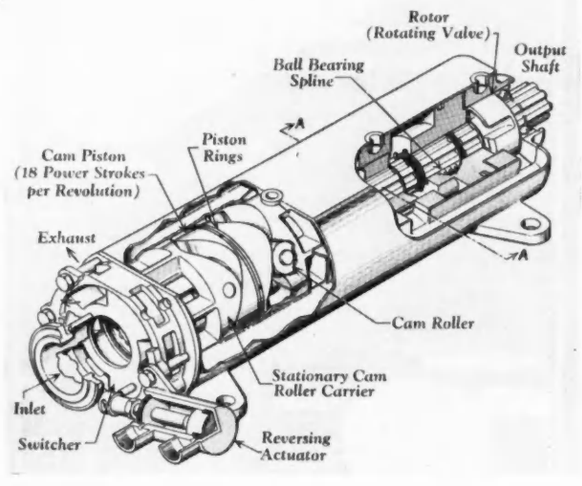


Fig. 1 Capable of operating at 1,000° F, the model 710 cam-piston air motor will develop 18·5 h.p. at 1,200 r.p.m.

A power source that can withstand the extremely high temperatures that are met with in missile and supersonic flight at speeds in excess of Mach 2, is the cam-piston air motor recently developed by the AiResearch Manufacturing Company, 402 South 36th Street, Phoenix, Arizona, U.S.A. The motive power is compressed air and the motor will operate at temperatures above 1,000° F without conventional lubrication or cooling.

Nearly cylindrical in shape, the typical model shown in Fig. 1 stands 3 in high and is 13 in long. For a weight of 22 lb it will develop 18·5 h.p. at 1,200 r.p.m. for an input air pressure of 200 lb per sq. in. The acceleration is very rapid — full speed can be reached in 0·5 sec—and it is directly reversing. The output is nearly linear with the inlet pressure. At 200 lb per sq. in air input pressure the starting torque is 1,800 in-lb.



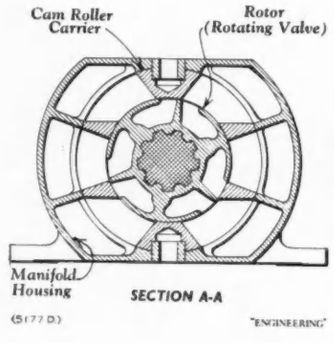


Fig. 2 Axial movement of the pistons is converted to rotation by the cam rollers.

Fig. 2 is a cut-away drawing showing the arrangement of the pistons. Air pressure on one side of the piston causes it to tend to move axially but it is constrained by the cam rollers so that any axial movement must be accompanied by a rotary one. The piston is ball-splined to the central shaft and therefore causes the latter to rotate also. In addition, the shaft carries a rotor which acts as a valve and directs the air to alternate sides of the piston as the latter rotates. In this way each piston gives six power strokes per revolution and as there are three pistons a total of 18 power strokes, equally distributed at 20° intervals, is obtained. For the model illustrated the piston diameter is 2·875 in and the stroke 0·6875 in, giving a total displacement per revolution of 71 cu. in. Performance curves are given in Fig. 3. The calculated pressure efficiency at 1,000 r.p.m. is 70 per cent.

The design allows a wide range of motor sizes to be made with powers from 1 to 300 h.p., depending on the air supply

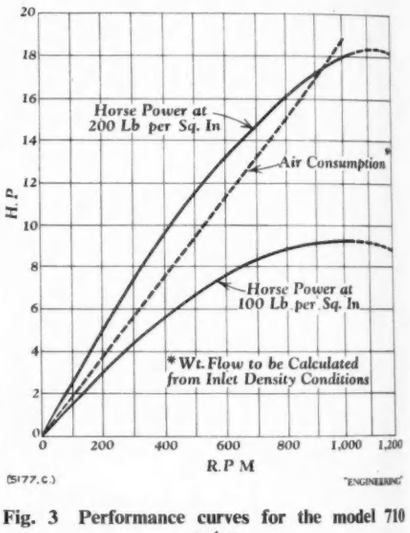


Fig. 3 Performance curves for the model 710 motor.

pressure available. By altering the stroke and cam contour the inherent speed can be selected. Output speeds from 400 to 2,500 r.p.m. are possible eliminating the need for reduction gearing. As an alternative to a rotary drive the output shaft can be coupled to a ball screw that will retract completely within the length of the body, and thus converts the motor into a high-performance linear actuator.

ELAND TYPE-TESTED AT 3,500 H.P.

The N.El.6 Eland propeller turbine aero-engine has passed a 150-hour type test for civil use under conditions laid down jointly by the Air Registration Board of the United Kingdom and the Civil Aeronautics Administration of the United States, at a sea-level take-off rating of 3,500 e.h.p. The Eland has also passed, at the same rating, a 150-hour military type test under conditions laid down by the British Ministry of Supply. The engine is made by D. Napier and Son Limited, The Vale, London, W.3, and will be produced at their Netherton Works near Liverpool.

STRUCTURAL ANALYSIS IN THE ELASTIC-PLASTIC RANGE

Floating Body Analogy

By R. J. P. Garden, A.M.I.C.E., A.M.I.STRUCT.E.*

In applying the Hardy Cross method of analysing structures, a modification has been introduced in that an " analogous floating body " is substituted for the Hardy Cross analogous column; the method has been applied to plastic as well as to elastic analysis.

Two changes are made from the form in which the analogous column is usually portrayed. Instead of a short column, a floating body of the same proportions is substituted. Obviously, the rising and falling of this body, under load, will be proportional at all points to the stresses caused in the column by the same load. Instead of having a distinction between the representations of static moments and restraining moments, the first represented by a weight on the column, and the second by a stress in the column, both are represented by changes in displacement of the floating body. This latter feature allows the exhibition of the combined static and restraining moments in final form, and this leads to the application of the analogy to plastic conditions, where it is necessary to allow for the change in elastic properties of the members as plasticity occurs.

Fig. 1 shows a fixed-end beam, an isometric view of the usual analogous column and an isometric view of the corresponding floating body. It will be noted that elastic loading due to static moments is represented by deflecting the body to the shape of the static, or free, moment diagram. The same procedure may be used to display the moments in any closed-ring structures to which column analogy computations are applicable.

The strain energy is directly represented by water displacement; moment-area principles and moment-distribution methods are clearly illustrated by the floating body.

As the width of the analogous body is inversely proportional to EI, where E is the modulus of elasticity and I the second moment of area, and as the onset of plasticity at any part of a member changes the value of EI, a floating body which is designed to represent elastic-plastic behaviour should progressively increase in width as the moment at that particular part increases from the moment at onset of yield to the full plastic moment. The effect can be achieved by conceiving a floating body having a cross-section of I-shape, so that, as any part of the body rises or falls in the water in direct proportion to the moment occurring in the corresponding part of the structural member, the width of the floating body at the water-line varies in proportion to the inverse of the varying value of EI. Fig. 2 shows an elevation and a cross-section of the floating body corresponding to a uniformly loaded fixed-end beam loaded to collapse. From this illustration of principles, a method of analysing elastic-plastic behaviour by the column analogy type of calculations can be derived. To use the method, charts are required of the plastic rotations against imposed moment.

Excellent methods have been published for determining collapse loads but convenient methods for full analysis for rotations, deflections and work done are lacking. The work described above provides a novel approach to the latter type of analysis.

Cyclo-styled copies of the full paper, from which the above has been extracted and which was presented to the 32nd meeting of the Australian and New Zealand Association for the Advancement of Science at Dunedin, New Zealand, on 27 January, 1957 are available from the author, P.O. Box 4, Dunedin, New Zealand, at 2*s.* 6*d.* each including surface mail charge, or 12*s.* 6*d.* for air mail.

* E. R. Garden and Associates, Dunedin, New Zealand.

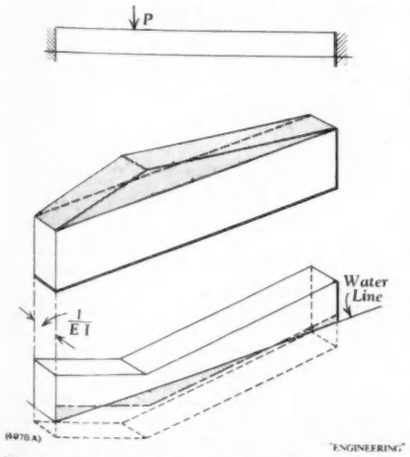


Fig. 1 Fixed-ended beam, the analogous Hardy-Cross column and the corresponding floating body which can be substituted for it.

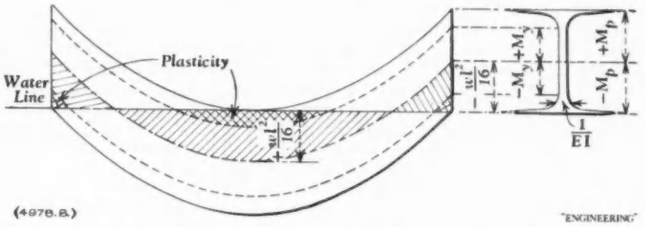


Fig. 2 Elevation and a cross-section of the floating body corresponding to a uniformly loaded fixed-ended beam loaded to collapse.

On the Shelf

By Frank H. Smith

Ever since I first received the Firth-Vickers Stainless Steels Limited's magazine *Enchiridion* I have wondered what it meant and now that I am to comment on it I thought I would make an effort. I wrestled with the *Britannica*, Latin dictionaries and Greek lexicons, but all to no avail. Then it occurred to me to look in my old friend the *Concise Oxford Dictionary*, and there it was: " a handbook," not even in italics to denote foreign origin. Anyway, the current number of *Enchiridion* has a most saliva-provoking section called " The Domestic Front," showing down-to-earth applications such as tableware, garden tools, a tea-trolley-cum-hotplate, copper-bottomed saucepans. But do not show it to your wife or you will let yourself in for a combined sink and washing machine entirely in stainless steel. Other applications shown come from Finland and Farnborough where the new wind tunnel uses stainless steel extensively. The container for the reactor at Dounreay, also made in this material, is described as the most complex vessel of its kind ever made in this country, and probably in the world.

The Society of Automotive Engineers Incorporated, 485 Lexington Avenue, New York 17, U.S.A., has produced a " checklist " of its special publications and meetings papers. It runs to 32 pages of typescript and the meetings papers are divided into 12 categories which I would quote had I more room. The Cambridge University Press have issued a " forthcoming " list for January-July 1958 and an enclosed leaflet draws attention to the first two titles in the Cambridge Engineering Series under the general editorship of Professor J. F. Baker.

Van Nostrand's, 358 Kensington High Street, London, W.14, " Postal Traveller " announces in the March issue, *Exterior Ballistics of Rockets*, by L. Davis, J. W. Follin and L. Blitzer, at 64*s.*, and *Shop Tools: Care and Repair*, by De Witt Hunt at 32*s.* The latter looks just the work for the do-it-yourself enthusiast and the final sentence in the publisher's announcement appeals to me: " Safety precautions not neglected "—curt and to the point.

A better-produced-than-usual firm's brochure is that of Canadian Applied Research Limited, Toronto. Part of the A. V. Roe Canada and Hawker-Siddeley set-up, its policy is " to make imaginative and practical use of the principles of mechanics, electronics, electro-mechanics and optics in designing fine instrumentation equipment . . . in the manufacture of devices for application in the fields of aviation, photography and photogrammetry for defense (sic), industry and commerce." It's strange how all these people design things for defence—never for attack.

The Power Petroleum Company, 76-86 Strand, London, W.C.2, have brought out a handsome 43-page booklet to celebrate the centenary of Rudolf Diesel, who was born on 18 March 1858. It traces the development and application of the diesel engine from its introduction in 1893 until the present day. Readers may like to be reminded that ENGINEERING published a two-part article on " Rudolf Diesel and his Invention " in the issues of 18 and 25 March 1949, pages 257 and 281.

A circular with a surprising amount of " meat " in its single page is GEN/4075 issued by the General Division, Board of Trade, Horse Guards Avenue, London, S.W.1 (Ref. GD/5597/58)—ring TRAfalgar 8855 Ext. 7656. It is entitled " Nuclear Power Developments Overseas " and outlines a United Nations publication *Electric Power in Asia and the Far East* 1951-55 (H.M. Stationery Office, price 4*s.* 6*d.*). It refers also to five studies prepared by the National Planning Association, 1600 New Hampshire Avenue, N.W., Washington 9, U.S.A., all of which deal with nuclear power, one in Japan, one in Brazil, one in Israel, one in India and one in Italy. A report on Pakistan is being prepared.

It is only comparatively recently that newspapers, and therefore " the man in the street," have appreciated the possible dangers of radiation, and, of course, nuclear power makes the subject even more newsworthy. For that reason, last year's Mackenzie Davidson Memorial Lecture, " On Some Biological Effects of Radiation," by Dr. F. G. Spear of the Strangeways Research Laboratory, Cambridge, may have more interest than usual. It is printed in the *British Journal of Radiology* for March, 32 Welbeck Street, London, W.1; price 6*s.* 5*d.*, post free.

The Central Library, Newcastle-upon-Tyne, has produced a 10-page " reading list " on " Management." The list is subdivided into general management, management education, production management, costing and finance, personnel management, industrial psychology, communication, automation, sales management, and research. No price is indicated, so perhaps it is gratis.

Production

LOADING VEHICLES MECHANICALLY

The loading and unloading of vehicles is an operation that occurs in almost every factory. It is one, too, that can consume a considerable amount of time and labour and frequently involves some manhandling. In order that the process should be brought more into accord with modern materials-handling, as it exists in factories, the Wayne Tank and Pump Company Limited, Western Road, Bracknell, Berkshire, have developed the Dock-o-matic loading ramp that enables fork trucks to run directly from the loading dock on to the lorry itself. The advantages are particularly great in those cases in which small items arrive, or are despatched, in containers or on pallets.

Fig. 1 The Dock-o-matic allows handling trucks to be run on to lorries of different height.

In essence the Dock-o-matic consists of a hinged platform that can be raised or lowered by a hydraulic cylinder, to rest on the floor of the lorry. The standard size made is 6 ft wide by 8 ft long and is capable of carrying a load of 20,000 lb. A typical installation is shown in Fig. 1 and the principles of construction and operation in Fig. 2.

The platform can be fixed to existing loading docks almost as easily as it can be built into new constructions. The only requirements are the grouting-in of the horizontal beam carrying the fixed portion of the hinge and the mounting of the spherical bearing for the cylinder. The whole of the operating mechanism apart from the control switch is mounted on the underside of the platform and is completely self-contained.

The platform is built up from two plates joined together by vertical channels for strength, while along the outer edge a strengthening tube also acts as the oil reservoir. The piston of the cylinder is not directly connected to the platform, which therefore only rests on it, but only by a link. This arrangement allows a certain amount of float in the platform to accommodate

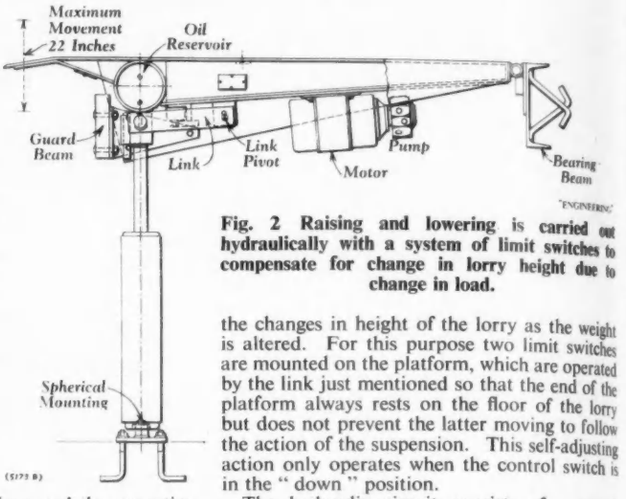


Fig. 2 Raising and lowering is carried out hydraulically with a system of limit switches to compensate for change in lorry height due to change in load.

the changes in height of the lorry as the weight is altered. For this purpose two limit switches are mounted on the platform, which are operated by the link just mentioned so that the end of the platform always rests on the floor of the lorry but does not prevent the latter moving to follow the action of the suspension. This self-adjusting action only operates when the control switch is in the " down " position.

The hydraulic circuit consists of a motor-driven pump feeding the cylinder through a filter and a relief valve. Lowering is carried out under gravity only. Although the platform will support a load of 20,000 lb in the horizontal (or any) position, the system is not designed to raise or lower more than the platform itself. The control switch can be put in any convenient spot and where, as in some cases, the outside doors cross the platform they should be interlocked to prevent accidents. As a rule the platform is set to give equal raising and lowering movements of 11 in, but this can be varied to suit particular cases, although the maximum movement of the standard model is limited to a total of 22 in.

PRODUCING TITANIUM INGOTS

What we are informed is the largest titanium-melting furnace in Europe came into operation during April at the Kynoch Works of Imperial Chemical Industries Limited, Metals Division, Witton, Birmingham.

The furnace is one of three supplied to the company by the Western German firm of W. C. Heraeus G.m.b.H., for the production of double-melted ingots of up to 4,200 lb in weight, by the consumable-electrode arc-melting process. It is shown in the accompanying illustration. The furnaces were delivered in January and the first one-ton ingot was produced a little over two months afterwards. A few days later an ingot weighing the maximum of 4,200 lb—the largest ever produced outside the United States, was successfully melted.

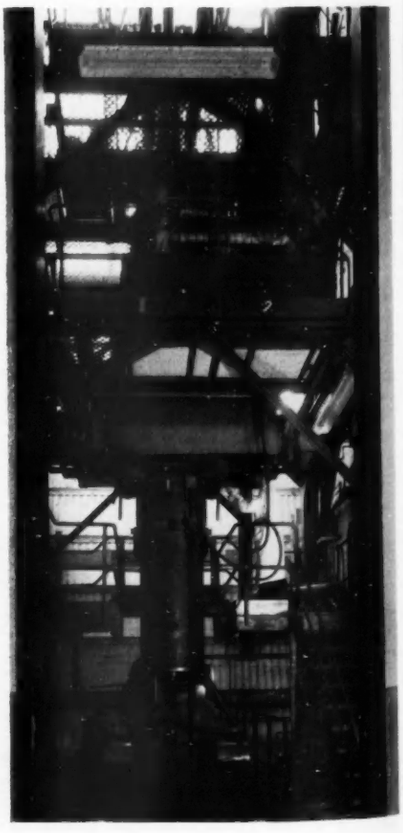
Apart from the prime advantage of producing these large ingots, the new equipment embodies several interesting features. The melting current employed is higher than that previously utilised in Europe for this purpose and this facilitates more complete melting and results in the production of ingots of improved homogeneity and better surface quality. The furnace plant operates normally under a high vacuum, a pressure of under 10 microns being maintained throughout a melt. Facilities for melting under reduced pressure and in the presence of an inert gas are also provided should this be required.

Particularly useful are features which reduce waiting time between melts and effect considerable improvements in furnace utilisation. One such device enables a first-melted ingot to be withdrawn into the upper portion of the furnace and held in vacuum while the larger diameter crucible, needed for the second melting, is fitted. Another device allows the second-melt crucible, containing the double-melted ingot, to be sealed by a plate valve and withdrawn from the furnace for cooling so that the furnace can be prepared immediately for another melt.

The hazards associated with titanium melting are now thoroughly understood and in the new installation all operations are carried out by remote control and the furnaces are installed in massive reinforced-concrete cubicles affording complete protection to all concerned. In the control room, optical systems give operators a clear view of the furnace interior throughout the melting process.

The availability of the very large ingots produced in the new plant offers two important advantages. In the first place it widens the scope of the fabricating techniques which can be applied to titanium. In particular, it makes possible, for the first time, the rolling of slab into long-length coils by strip-rolling techniques without the necessity for welding small coils together. In the second place, it increases the yield by decreasing the surface : volume ratio. Any reduction in process scrap is a most significant factor because titanium is still a relatively expensive metal.

In 1955, 18 furnaces were needed for an output of 1,500 tons a year. The present installation of three furnaces suffices to produce over 2,000 tons a year, and this increased capacity is likely to open up still further outlets for titanium in the aircraft, chemical-plant and other industries.



Fully assembled electric-arc furnace for melting titanium ingots of up to 4,200 lb in weight. The furnace is installed in a reinforced-concrete cubicle, the door of which is closed during melting.

CONTINUOUS SOLDERING OF PRINTED-CIRCUIT PANELS

The introduction of printed circuits on flat plastics panels or boards has facilitated the production of many types of electronic instruments and is also used extensively in the assembly of radio and television sets, telephones, computers and other instruments.

A new machine designed to eliminate the difficulties and problems involved in the conventional flat dip-soldering of the circuit panels after printing and preparation has been evolved by Fry's Metal Foundries Limited, Tandem Works, Merton Abbey, London, S.W.19. In this Flowsolder unit, as it is called, the molten solder is lifted to the circuit panel, in contrast to ordinary dip-soldering in which the panel is lowered down on to the surface of the molten solder. The molten solder is raised up to the circuit panel by an impeller pump, which forces the metal upwards through an elongated nozzle so that it forms a stationary wave. The panel is passed through the crest of this wave, which solders the joints between the component leads and copper conductors under the panel.

The Flowsolder machine consists of two compact parts; the electrically heated solder unit which contains the molten metal and the pump, and the control unit which houses the electrical regulating gear.

The solder unit consists of a mild-steel rectangular tank, holding some 550 lb of molten solder; a heat-insulating casing is provided. As stated above, the wave of molten solder, 8 in in length, is produced by pumping the metal through a conduit ending in an elongated, narrow, horizontal aperture or nozzle which projects slightly above the surface of the solder. The metal wells up through this nozzle and flows over the two long edges and returns to the metal bath. The height of the wave is easily regulated by adjusting the speed of the pump. The conduit and metal pump are completely immersed in the molten solder. The solder in the bath is maintained liquid by two electric immersion heaters each rated at 2·25 kW. The bath temperature is thermostatically controlled at a temperature between 220° and 250° C. The molten-metal pump is driven by a variable-speed geared motor through a belt and pulley, the level of the metal bath being maintained constant by a float-controlled ingot feeder.

The adjoining control unit of the Flowsolder machine contains a main switch with a pilot light, and a time switch which turns on the heaters early enough in the morning for the machine to be ready for operation at the beginning of a working day; the solder bath takes approximately 2½ hours to heat up to the working temperature from cold. The time switch turns off the heaters at a pre-set hour at the end of each working period and day-omitting devices maintain the heaters off at week-ends.

Other equipment in the control unit includes a temperature-indicating thermostat, an ammeter, a motor speed-control mechanism and a voltage stabilising device to ensure that the pump motor speed is independent of voltage fluctuations.

No skimming of the metal is necessary as the molten solder welling up through the nozzle is drawn from below the bath surface and is therefore always clean and free from oxide or dross. Another advantage of the process is that only a 2 in wide strip of the panel is in contact with the molten solder at any given time, thus reducing any danger of the warping of the panel, and heat damage to the components.

The machine with its 8 in nozzle will handle panels up to 7½ in wide and of any length.

PROCESS CONTROL BY INSPECTION IN METALLURGY

Automatic gauge control in strip rolling mills, the use of ultrasonic testing for the control of quality and the detection of flaws in metals, and the control analysis of aluminium alloys by self-recording spectrometers were among the subjects dealt with at a symposium, on "Advances in Inspection Techniques as Aids to Process Control in Non-Ferrous Metals Production," arranged by the Metallurgical Engineering Committee of the Institute of Metals and held during the Golden Jubilee Spring Meeting of the Institute, which took place in London from 28 April to 2 May.

CONTROL OF STEEL-STRIP QUALITY

Ten papers were submitted for discussion, the first of which was by Dr. R. B. Sims, of Davy and United Engineering Company Limited, Sheffield. He stated that automatic gauge control (or A.G.C.) in strip rolling mills had been the subject of development since the 1930's, when the first practical method of continuous gauge measurement on moving strip had become available. Two methods of gauge control had originated in an error-sensing device known as the Gaugemeter (which was described in our columns in vol. 175, 1953, page 33). The strip material had negligible elastic recovery and, to a very close approximation, the mill-roll gap was equal to the thickness of the rolled strip. This form of measuring equipment, in which the rolling mill itself was used as a strip micrometer, was termed the Gaugemeter and the two methods of gauge control were, respectively, the A.G.C. (S) or screw-down type, and the A.G.C. (T) or tension type. A logical development had been to combine both types into one controller deriving its error signal from a single Gaugemeter unit. This was a closed-loop controller, which would operate stably at all rolling-mill speeds above zero. It was capable of utilising the full speed of response of both the tension and the screw-down systems. The controller would operate within pre-set dead-zone limits down to ± 0·00025 in on the screw-down control, and the tension control would operate without a dead zone and was limited in accuracy only by the sensitivity and stability of the measuring device.

In the second paper on "Strip-Thickness Measurement by Beta and Gamma Absorption," Mr. E. B. Bell, of Isotope Developments Limited, Aldermaston Wharf, near Reading, stated that the need for thickness and density measurement in process control had led to the development of a series of instruments based on the absorption and scattering of β and γ-rays by matter. The instruments employed set out to measure thickness or density by determining the intensity of the radiation transmitted through the inspected material. They indicated the difference between a nominal gauge setting and the actual thickness and gave zero output when the correct gauge was being maintained. The detector was basically a radiation-energy/electrical-energy transducer and its electrical output was small. Amplification was necessary to provide a signal capable of operating a control mechanism or off-gauge indicator.

The third paper on the control of steel-strip quality was by Mr. S. S. Carlisle and Mr. J. H. Wilson, of the British Iron and Steel Research Association, Swansea, and dealt with the non-destructive measuring and inspection techniques developed for use on continuous steel-strip processing lines and in tin-plate manufacture. The techniques included the measurement of coating thickness by X-ray fluorescence, the measurement of strip width and thickness, and the detection of pin-holes and lamination.

An improved instrument, developed in 1954 by the Physics Department of the British Iron and Steel Research Association and now in service on some hot strip rolling mills in the United Kingdom, made use of the infra-red radiation emitted by the strip. It consisted of two telescopic-like viewer units mounted vertically above the two edges of the strip at a height of about 10 ft. (Apparatus utilising these principles was described and illustrated in our issue of 21 March, on p. 382.)

An X-ray fluorescence method for the non-contact measurement of the thickness of tin coatings on steel had been developed and the first instrument made by Newton Victor Limited, London, was now being installed at the Velindre Works of the Steel Company of Wales Limited. The working principle involved the illumination of the surface under study by an X-ray beam of a wavelength chosen to induce fluorescence of the iron base but not of the tin. The iron fluorescence shone back through the tin and was attenuated in accordance with the tin-coating thickness. Thus, by measuring the intensity of this fluorescent radiation with a Geiger counter or by similar means, the coating thickness could be determined after suitable calibration. This first British instrument had been designed for laboratory use and it read the coating weight from 0·25 up to 1·5 lb per basis box.

For continuous measurement in the electrolytic tinning line, the further development of this instrument was under consideration with a view to improving the speed of response.

OTHER INSPECTION TECHNIQUES

Of the remaining seven papers discussed two dealt with ultrasonic testing. The first of these, on ultrasonic testing in the manufacture of aluminium alloys and other non-ferrous materials, was by Mr. J. G. Harris and Mr. J. Crowther, of James Booth and Company Limited, Birmingham. These authors were of the opinion that the increasing use of ultrasonic testing in the final inspection of materials and at earlier stages in processing had led to a marked improvement in the quality of high-strength aluminium-alloy plate, extrusions and forgings. The greatest activity at present was being directed towards two problems, namely, the standardisation of measurement in the final inspection, and the correlation of ultrasonic signals with the elements of the metallurgical structure which gave rise to them.

The other paper, on "Instrumentation in Ultrasonic Flaw Detection," was by Mr. D. G. W. Claydon, of Aluminium Laboratories Limited, Banbury, Oxon, who stated that of the several methods of flaw detection making use of ultrasonic vibrations, the "Pulse-Echo" method was the one in most common use. Until just recently considerable emphasis had been placed on the portability of flaw detectors, a necessary feature in some instances. Too much attention, however, had been devoted to this feature, perhaps to the detriment of other important aspects.

Two papers dealt with eddy-current testing. The authors of the first, Mr. J. B. C. Robinson and Mr. L. T. Perriam, of Imperial Chemical Industries Limited, Metals Division, Birmingham, referred to "The Inspection of Tubes for Flaws and Variations in Thickness." In describing the general principles of the method, they stated that if a coil supplied with alternating current were placed in proximity to a metal, the apparent resistive and inductive parameters of the coil would be modified by the field produced by eddy currents induced in the metal.

Internal and external coil systems were used at the tube making works of the authors' firm for flaw testing condenser and heat-exchanger tubing, and automatic driving arrangements were employed to obtain high speeds of testing. Flaws such as inclusions, laps, spills, dents, "ovality" and "chatter" were quickly found and could cause rejection levels up to 25 per cent in tubes which were acceptable by normal visual standards of inspection. Careful consideration, however,

Continuing Production

was given to the reasons for rejection in conjunction with the results of visual examination.

The second paper, on the " Use of a Search-Coil Apparatus for the Eddy-Current Testing of Copper and its Alloys," was by Mr. N. B. Harvey, of the Aston Chain and Hook Company, Limited, Birmingham. He stated that an eddy-current instrument, designed by the Dr. Förster Institute at Reutlingen, Württemberg, Germany, and known as the " Conductitest," was now available commercially. It was capable of the rapid and direct determination of the electrical conductivity of a test-piece. It was portable, reliable and accurate to within $\pm$ 0·5 per cent at 100 per cent conductivity. It was used mainly for the quality control of copper and its alloys, for the indirect measurement of tensile properties in age-hardening copper alloys, for the sorting of scrap and for flaw detection.

Of the remaining three papers, one was by Dr. C. E. Ransley, Mr. D. E. J. Talbot and Mr. H. C. Barlow, of the Research Laboratories of the British Aluminium Company, Limited, and described " An Instrument for Measuring the Gas Content of Aluminium Alloys during Melting and Casting." The authors stated that the instrument finally evolved for their purpose depended on the circulation of a small stream of nitrogen through the molten metal. The volume of gas circulated must be maintained very small, namely, from 2 to 3 cc at standard temperature and pressure, and this had made it necessary to develop a special pump, valves, and analysis Katharometer (or hot-wire conductivity gauge) for the purpose. When the instrument was employed in a convenient situation such as a transfer launder, it had been found possible to maintain a continuous observation of the quality of a melt during the actual casting operation.

Another paper dealt with " Control Analysis of Aluminium Alloys and Copper Alloys Using Self-Recording Spectrometers," and was by Mr. M. Milbourn and Mr. J. A. F. Gidley, of Imperial Chemical Industries Limited, Metals Division, Birmingham, who said that their work had been conducted with three different spectrometers, each employed for a separate purpose. An ARL (Applied Research Laboratories) 1·5 m production control Quantometer was used for the complete analysis of aluminium alloys; a Hilger 3 m grating Polychromator for determining several constituents in a range of copper alloys and a Hilger medium spectrograph, with direct-reading attachment, for development work connected with the analysis of copper alloys.

The work had shown that the rapid availability of accurate analytical results on aluminium alloys had allowed the full compositional control of the casting process to be established, with consequent economies in conversion costs, the use of raw materials and stock handling, and with a more uniform finished product and reduced analytical effort. The control of copper alloys had been effected for several constituents.

The last paper of the symposium, on " Recent Advances in Radiographic Techniques," was by Mr. R. Halmshaw, of the Armament Research and Development Establishment, Fort Halstead, Kent, who stated that radiography, as a method of non-destructive testing was now a well established technique. Of late years, there had been improvements in X-ray apparatus, particularly in portability; new radioisotope γ-ray sources had become available, and radiographic films had improved in speed. It was perhaps in the directions of extended scope and reduced cost that the chief advances had been made.

Engineering at Home

AVAILABLE STEREOPHONY

Stereophonic records on discs are to be put on the market by the Pye group of companies. The equipment for playing the discs has been developed by Pamphonic Reproducers Limited and Pye Limited; the records are to be issued regularly by Pye Records Limited. Also, the BBC are to make stereophonic broadcasts during Radio Record Week, in May, to illustrate the recent advances in recording techniques and to give listeners the opportunity of judging the effect in their own homes.

Briefly, the system attempts to create the impression of a live performance by the use of two recording channels. Two loudspeakers are used and the intention is that the sound should appear to come from the whole area between them and that individual instruments should be heard coming from a particular direction, corresponding to their original placing in the orchestra recorded. The system is thus designed to serve both ears of the listener rather than to give the monaural effect obtained with a single loudspeaker, or loudspeakers spaced close together. Previous references to stereophonic sound have been made on p. 224 and p. 448 (14 February and 4 April) this year.

Pye Limited say that with their system the listener does not have to place himself on the centre line between the two speakers. The effect to the " off centre " listener is similar to that heard by a listener who is off the centre line in a concert hall. In the average home the loudspeakers can be placed about the width of a fireplace apart—then listeners sitting more than 9 ft away will get the full stereophonic effect. The distance between the speakers is not critical, but it does govern the apparent width of the sound picture created. As a general rule, the distance the listener sits from the speakers should be about 1·5 times the distance between the speakers.

The stereophonic records will be available on 12 and 10 in discs playing at 33⅓ r.p.m., and on 7 in discs playing at 45 r.p.m. The records carry two signals cut in the walls of the record groove, which are inclined at 45° to the record surface. They are played by a specially designed stylus which is capable of separating the two signals and presenting them to two amplifiers, which in turn feed the two loudspeakers. The company say that the new records will cost about 25 per cent more than conventional records. The first issues will be on sale in May and further issues will be made every two months.

Pamphonic Reproducers Limited are to have a stereophonic system on the market by June. The cost will be about £80. The system consists of an amplifier, two speakers, and a stereophonic transcription unit. Two complete push-pull amplifier circuits are embodied in the amplifier and they can operate from a stereophonic crystal pick-up or from a stereophonic tape recorder. At a turn of a switch, the amplifiers can be used to play conventional records. In this position the output is 15 watts; when used stereophonically the output is 7·5 watts.

Pye Limited, Box 49, Cambridge, will be offering a system costing about £60. It produces 3·5 watts of stereophonic sound. The two loudspeakers are elliptical, 10 in by 6 in, and can either be wall mounted or placed on tables. A booklet on how stereophonic reproduction works is available from the company on request.

The sounds emitted by the two loudspeakers in a stereophonic system differ slightly. For a realistic effect to be obtained the left ear of the listener must be towards the speaker carrying the left-hand channel and his right ear must be towards the one carrying the right-hand channel. In the BBC experiments the two channels will be carried by different groups of transmitters. If listeners are to obtain a stereophonic effect they will require two radio receivers or a radio receiver and a television set. The experimental broadcasts will be made as follows:

10.30–11.00 *a.m., Sunday, 11 May*

Left-hand channel	Right-hand channel
All Home Service transmitters (medium wave and VHF)	All Third Programme transmitters (medium wave and VHF) and all television sound transmitters

11.00–11.30 *a.m., Saturday, 17 May*

Left-hand channel	Right-hand channel
All Light Programme transmitters (long wave, medium wave, and VHF)	All Third Programme transmitters (medium wave and VHF) and all television sound transmitters

Whichever two receivers are used, they should be placed from 6 to 12 ft apart facing the listener. He should be at the same distance from each receiver, the left-hand one being tuned to a left-hand channel, the right-hand one to a right-hand channel. For a stereophonic effect to be obtained the volume controls of the two receivers must be adjusted until the sound during the initial test speech appears to be coming from a point midway between the two loudspeakers. To produce the effect, the two loudspeakers must be in phase, that is, the loudspeaker cones must move forward or backwards together. Whether this is so or not is a matter of chance and there is usually no easy way of reversing the connections to one loudspeaker. The BBC will therefore reverse the phase of one channel half-way through the experiment, which should ensure that all listeners will have the right conditions for half the time. There are, however, receivers that have an external two-pin socket connecting the set to the loudspeaker; if this is changed over at half-time, conditions can be made right throughout the broadcast.

Listeners in the London area should get a pronounced stereophonic effect if their loudspeakers are in phase. In other parts of the country the effect will be modified by the land-lines connecting the London studios with the various transmitters, and will vary from one part of the country to another.

TIME ON

It is often desirable to know how long a piece of electrical equipment has been working—either continuously or intermittently. A gramophone needle, for example, is best discarded after it has played for a specific length of time, otherwise records will wear unduly. Mr. M. Hoberman, chief engineer, Bergen Laboratories, Clifton, N.J., U.S.A., has produced a simple time indicator, accurate to about 5 per cent, which is suitable for such applications. It is called the " Chronistat " and is described in the *I.S.A. Journal* of March 1958.

The "Chronistat" is an electrolytic device that is mounted in parallel with the equipment. When a direct current flows through the electrolyte, metal ions are removed from the anode and it gets shorter. A time scale alongside the anode is calibrated in hours. The device has a built-in rectifier.

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